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THE POTENTIAL AND LIMITATIONS OF RE-USING AND RECYCLING OF CONSTRUCTION PRODUCTS FROM THE PERSPECTIVE OF CIRCULAR ECONOMY

Master’s thesis for the degree of Master of Science in Technology submitted for inspection, Espoo, 9th August, 2016.

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Tiivistelmä

Diplomityössä selvitettiin kiertotalouden malliin parhaiten sopivaa ratkaisua rakennus- ja purkujätteen käsittelyyn. Arviointi suoritettiin tutkimalla ensin kiertotalouden määritelmiä sekä aiheeseen liittyvää lainsäädäntöä. Näkökulma rajattiin pääasiassa Suomeen, mutta koska suuri osa lainsäädännöstämme tulee EU:n tasolta, on myös tämä näkökulma otettava huomioon.

Työssä käytettiin Case-esimerkkinä Ruukki Constructionin Sandwich-paneelia. Paneeli koostuu kahdesta teräslevystä, jotka ovat liimattuina eristeenä käytettävään mineraalivillaan. Kantavana kysymyksenä oli selvittää, mitä paneeleilla voi tehdä niiden ensimmäisen käytön jälkeen niiden teknisten ominaisuuksien puolesta ja vastaavasti, mitä lain puitteissa niillä on sallittua tehdä.

Tutkimustyötä suoritettiin muun muassa kirjallisuustyönä, lainsäädäntöä tutkimalla, laitosvierailujen sekä haastattelujen muodossa. Saatujen tietojen perusteella muodostettiin kuva kaikista niistä säännöistä, jotka liittyvät joko käytetyn rakennusmateriaalin kierrättämiseen tai sen uudelleenkäyttöön. Nämä EU:n jätehierarkiassa esitettyä kaksi vaihtoehtoa sopivat parhaiten kiertotalouden asettamiin tavoitteisiin.

Lopulta päädyttiin siihen, että paras ratkaisu olisi uudelleenkäyttää mahdollisimman paljon tuotteita sellaisenaan prosessiin tarvittavien resurssien antamissa rajoissa. Mikäli uudelleenkäyttö ei ole mahdollista, materiaalin kierrätys on toiseksi paras vaihtoehto. Suuressa mittakaavassa uudelleenkäytön lainsäädännöstä johtuvat rajoitukset aiheuttavat sen, että materiaalin kierrätys voi olla kannattavin tapa.

Avainsanat Kiertotalous, Rakennus- ja purkujäte, kierrätys, uudelleenkäyttö

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Abstract

This thesis is a study about finding the best solution for construction and demolition waste promoting the views of circular economy. The study was conducted by researching the definitions of circular economy and the relevant legislation concerning this issue. The scope of this thesis is limited mainly to Finnish legislation, but since most of it comes from the EU also this has to be taken into account.

This thesis has a case example of Ruukki Construction Sandwich panel. These panels are used to build industrial halls and storages. They consist of two steel sheets connected with adhesive to isolative mineral wool core. The main question was to find out first what can be done with the panels after their initial life, and what is allowed to be done in terms of legislation.

The research was done as a literature review, studying both EU and Finnish legislation, conducting interviews and plant visits. With gathered information a comprehensive overview was done for all the rules set for re-using and recycling of construction and demolition waste. These two possibilities presented in the EU waste hierarchy are the options that will promote the model of circular economy the most.

The analysis shows that the best option purely from the view of circular economy would be re-using most of the products within the limits set by available resources. If re-using is not possible the second option would be recycling the material. In large scale the limitations for re-using may cause that recycling of material is the most viable option.

Keywords Circular economy, Construction and demolition waste, recycling, re-using

Acknowledgements

This master's thesis is a part of Fimecc's Hybrid materials program. It belongs to a project called Light multifunctional hybrid structures which is a part of this program. In the project, this thesis is situated under the sub task called Design and manufacturing of functional Sandwich and reinforced composite structures.

I thank Ruukki for the opportunity to make this thesis as a part of their project, and for funding it. From Ruukki personnel I want to thank Harri Kemppainen who was my original advisor, and Pasi Turpeenniemi who provided additional information and contacts throughout the writing process.

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I want also thank my coordinators from Aalto University. My advisor Nani Pajunen, and my supervisor Rodrigo Serna provided great support and guidance throughout the whole thesis. Without their support, this thesis would not have been completed. I thank also my friends and family for support during this long process.

Severi Ojanen

Espoo, June 3rd 2016

Abbreviations:

EU	European Union
CDW	Construction and demolition waste
CE	Conformité Européenne, European Conformity
UNEP	United Nations Environment Programme
GDP	Gross domestic product
PPP	Public-private partnership
BAT	Best available technology
WFD	Waste Framework Directive
CJEU	Court of Justice of the European Union
EoW	End-of-Waste
EEA	European Economic area
Tukes	The Finnish Safety and Chemical Agency
hEN	Harmonized European Standard for a Construction Product
ETA	European Technical Assessment
AVCP	Assessment and Verification of Constancy of Performance
DoP	Declaration of Performance
CPR	Construction Product Regulation
MLR	Maankäyttö- ja rakennuslaki, The Land Use and Building Act
Ess. Char.	Essential characteristics
WEEE	Waste electrical and electronic equipment

Contents

1. Introduction

The world's population is constantly increasing. This means that demand and consumption of raw materials is also growing rapidly. This growth must be addressed with an equally growing production and offer. Especially the demand in developing countries is significantly increasing. At this rate, raw materials will soon be depleted. At the same time, the amount of waste generated is also increasing (Lieder et al. 2016). Much of usable material is lost in the ever growing streams of waste and ending up in landfills. Not only this means valuable materials get lost, but it also results in serious environmental impact. The current approach to raw material production is not sustainable and alternatives should be found to promote more sustainable practices.

At the time this work is being written, the European Union (EU) area has been in a depression for a number of years. The financial crisis in 2008 caused a drop in economic growths all around the world. It hit especially the EU, which has not completely recovered from it yet. Other areas like China and North America have managed to get their economy back on its feet faster and now the EU area is lagging behind. Natural resources of Europe are also running out because of prolonged use, which gives other regions a comparative advantage. By effectively utilizing the waste streams as sources of raw material the EU may find a strategy to alleviate its need for raw materials. At the same time, new business fields dealing with waste stream processing could be opened, generating employment and promoting growth.

There is also a political point of view. By showing that goods produced domestically or at the EU-level using recycled material or following a design-for-recycling approach, their popularity could be increased. This would act as a sign to other actors in the markets as well that this aspect has to be taken into consideration. If a uniform set of rules could be taken and implemented in the EU area, it would also bring different countries closer and help them keep the interests of the general population in mind.

Construction and demolition waste (CDW) is the second largest waste stream, right after waste produced by the mining industry in the EU area. These two are remarkably larger (Statistics of Finland 2013) than all other waste generation sources combined, which brings up importance of reducing them in order to have a significant impact on the amount of the total waste generated. While the mining industry has its own methods and challenges regarding waste treatment, this thesis focuses on the waste generated in construction industry and its particular challenges. Traditionally, a significant amount of CDW is disposed into landfills which is the least sustainable option. For example, in 2002 55% of CDW total was taken to landfilling, while only 45% received any kind of recovery operations (Kourmpanis et al. 2008). Landfilling effectively prevents the re-use of potentially useful raw material and makes its collection much more difficult in the future. Landfilling has also many environmental issues such as forming of greenhouse gases or leachates spoiling ground water (El-Fadel et al. 1995), which makes it even worse. Consequently, this practice must be changed.

In order for the general development of material efficiency to be sustainable and to ensure availability of raw materials, landfill disposal of CDW should somehow be discouraged. One possible solution would be to aim towards the implementation of a circular economy model. According to this model, the materials are reprocessed and recycled within the system instead of leaking out in a form of waste streams. In principle, the idea behind the circular economy is to try mimicking natural ecosystems where waste can always be used, thus keeping a balance between waste production and consumption. This could be achieved by improving material efficiency. The goal would be to reduce the total amount of waste generated by intensifying the use of materials, for example by recycling them after their initial lifetime or by re-use of working products without further processing in a similar use. Products and materials should also be designed to maximize their life cycle, the main challenge being how to make them more durable and easier to maintain.

Since the circular economy model comprises all economic sectors, it can also be implemented into the construction business. This is because of immense volumes of waste generated by this sector. Ruukki Construction’s Sandwich panel will be used as a case study in this thesis. This panel is a good example because it offers a design that makes its components possible to be re-used after the structure they are part of has come to the end of its life. The steel covers are very durable and panels are expected to have a long life if maintained appropriately (Ruukki Construction 2016a). A main issue, however is not the durability or recycling potential of these panels, but the applicable laws (Hakaste and Peuranen 2015). It is of much interest to industry to determine whether the re-use of construction panels is allowed under current legislation. There are also some unknown facts in the recycling of these panels and the materials they consist of, which are necessary to shed clarity on the regulations applicable for the aforementioned purpose.

This master's thesis is a part of Fimecc's Hybrid materials program. This program is about creating multidisciplinary world-class competence and technology platforms for Finnish industry to gain key advantage of applying advanced materials efficiently in their future applications. The goal is to increase the competitiveness of Finnish companies in international markets of high-technology products. The program itself can be divided into five projects which are Multifunctional thin coatings, Multifunctional thick coatings and composites, Light multifunctional hybrid structures, Polymer multifunctional sliding materials, and Fundamentals and modelling. This thesis is a part of the third one. Light multifunctional hybrid structures project is divided to three tasks, which are Design and manufacturing of functional Sandwich and reinforced composite structures, CF NDE-methods and intelligent sensoring, and Long term durability of hybrid structures. This thesis belongs to the first one of these and is a part of subtask called Drivers behind the recyclability, which is about the co-operation between the companies of the whole supply chain all the way from design to recycling. One of main themes is that products should be designed so that they can be efficiently recycled or re-used at the end of their initial life.

The goal of this thesis is to find out what is technologically feasible and what is currently allowed within the boundaries of legislation with Ruukki Construction Sandwich panels after their initial use. Ruukki Construction is a division of the steel company SSAB. The aim is to find out what would be the best options to prolong its life cycle. Life cycle in this context means all the consecutive stages of a construction product's life, from raw material acquisition or generation from natural resources to the final disposal (Regulation (EU) No. 305/2011). In this study, a closer view to the current situation of the construction and demolition waste, which is the class under which Ruukki Sandwich panels fall, will be done. This will be looked from the perspective of circular economy also presented in this thesis.

First, the research methodology will be presented. In that chapter, the methods used to gather information for this thesis are listed. The second chapter is the background chapter where the concept of circular economy will be presented: What does it mean, how is it pursued by EU, and what kind of benefits could be achieved by adopting it. This will lead to the concept of waste in general and some additional focus on the class of CDW. Different options for treatment of waste will be described through analyzing EU's waste hierarchy. After this, a case study is introduced: Ruukki Sandwich panel will be presented in general as well as its use and manufacturing processes. In the fourth chapter, the acquired results will be presented:

Information gathered from each interview and plant visit will be taken into discussion for further analysis and the conclusions will be made be on the basis of this. In the end, there will be some recommendations for the future and possibilities for additional research.

2. Research Methodology

In this chapter the research methodology is explained. To gather sufficient data for the purposes of this thesis the data was gathered at various levels, these being data from literature, data from interviews and plant visits, and data received from project workshops.

2.1 Project Workshops

This thesis is part of a wider project named "Drivers behind the recyclability", which is in turn part of Fimecc's "Hybrids" program. This project studies the use of applying advanced materials in the right applications to guarantee high performance, cost-efficiency, safety, and long service lifetime for products. The name "Hybrids" comes from the fact that many of these applications require properties that can only be acquired by completely new types of combinations. These combinations can also be different technology platforms and networks. The ultimate goal of this project is to provide an advantage to the Finnish industry by applying these novel materials and methods.

Ruukki Construction and Aalto University organized the "Innovation Afternoon" on 24.6.2015, which was a day where people from different industries and backgrounds gathered together. Representatives from various economical sectors, including the construction industry, artists, and architects were present. Themes for this day were Circular economy, upcycling and innovation. The questions and topics for the day were the difficulties and challenges faced by societies executing the principles of circular economy. How could we improve our current products or develop completely new ones so that they would fit into this model or should we change the whole way we are viewing the world. What happens to products and materials when their life has come to its end?

This led to the main assignment for the afternoon. Participants had to design ways to re-use the Ruukki Sandwich panels in the most innovative ways. Because of the different backgrounds of the attendees, the results were very interesting. Some proposed that panels could be re-used as building blocks for smaller dwellings, while others wanted to turn them into sculptures and some even planned using them as shelters for wild animals. The organizers collected the results and took them into further analysis.

The next event for this project took place on 27.10.2015, this time called "Upcycling workshop". The purpose of this workshop was to actually produce something out of pieces of Ruukki Sandwich panels. Again, the attendees had very different backgrounds, which led completely different approaches on this problem. Some people designed more functional objects like furniture and movable walls and other different sculptures. One particularly interesting idea was to use a bigger piece of panel as a living wall where plants could be located in spaces made for them and the panel itself would store the water needed.

2.2 Literature review

Most of the data presented in the first part of this thesis was gathered from the EU legislation and from their official publications. There is also material taken from the Finnish law and other official reports by local authorities. Some articles have provided useful information. There was also an overview on the future plans in the EU legislation.

Because nearly all of the rules and regulations for the use of construction products comes from the EU legislation, most of the data used in the first part of this thesis was acquired from EU legislation and from their other official publications. This includes their official webpage, which has information targeted to regular actors on the markets, for example, to obtain official certificates and other approvals needed. Since the EU legislation leaves room for local authorities, some of Finnish legislation that describes in more detail how things are done in national level has also been consulted. As legislation is always developing, the future plans of the EU and public sector reports on their own research were followed, in order to get an insight on what possible changes in their legislation may occur in the near future.

A number of scientific articles are used in defining terms like circular economy and the philosophy behind it. The EU has also its own goals and plans for implementing the model of circular economy, which will act as a base for describing the model. One major contributor for defining the circular economy is the Ellen MacArthur foundation. They are trying to promote and create definitions for circular economy and the data from their website will be used.

Ruukki Construction provided the data about their product used in this thesis. All that is presented here is based on public material that can be found on their website. All the technical details and certificates are taken from their official website or from the data received during plant visits.

2.3 Interviews and plant visits

A major part of the data for this thesis was gathered by conducting interviews with experts in fields relevant to this work. The goal was to get opinions for each critical step of the life cycle described in the simplified model of material flows in circular economy (as will be presented in chapter 3.1.1.) i) source of raw materials, ii) manufacturing of a product, iii) use of a product, iv) waste treatment, and v) recycling or re-using of a product. Dedicated experts working in each of these phases were chosen for the interviews. The companies and legislative bodies along with the major questions posed are shown in Figure 1.

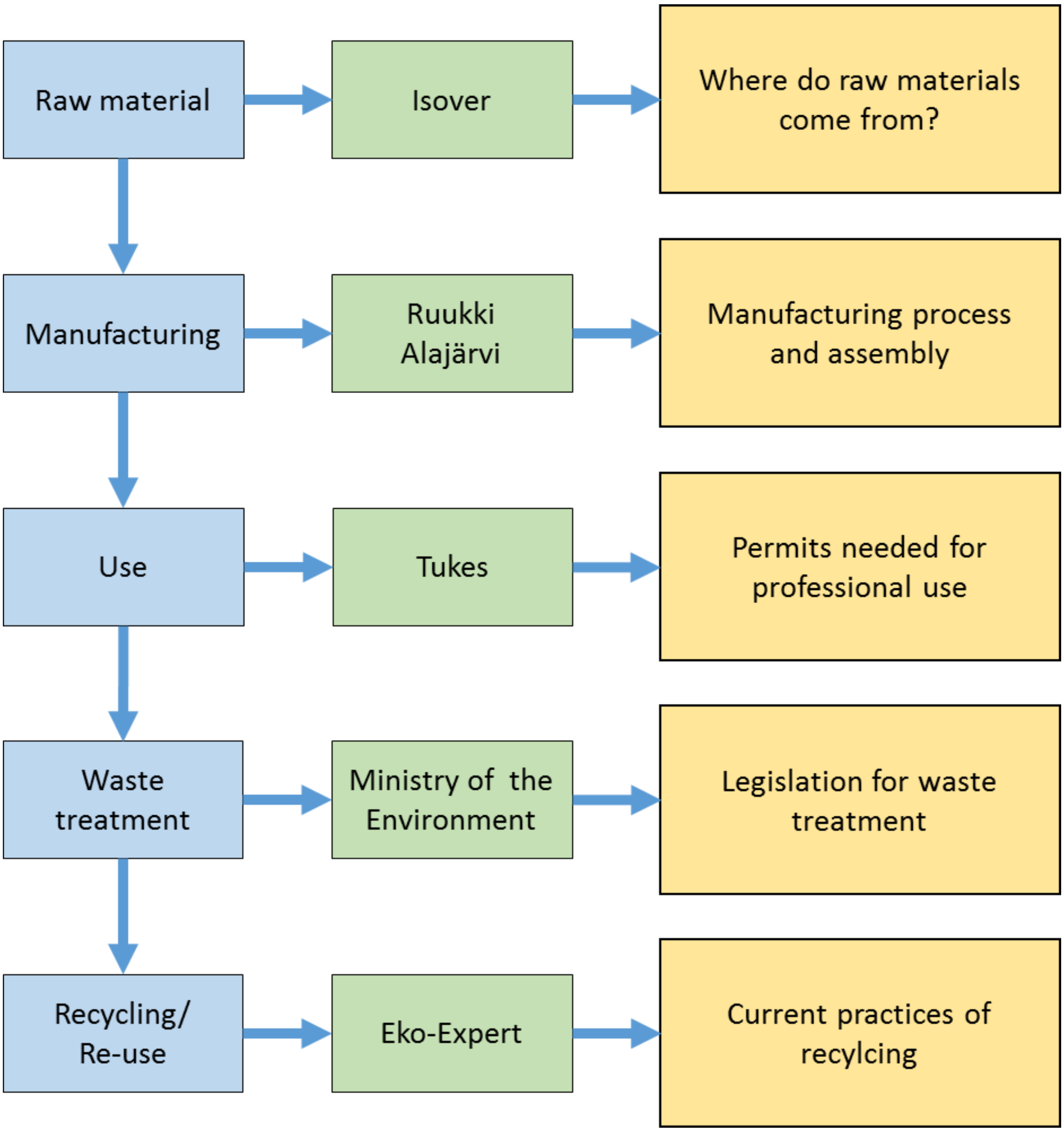

Figure 1: Interviews and plant visits placed on the life cycle of the product, complete with a main question for each. Blue ones show the place in the life cycle track, green ones show the place visited, and yellow ones the main question for each.

The interview for the raw material phase was done as a plant visit to Isover's mineral wool plant in Hyvinkää. The visit was done September 2nd 2015. Isover is a part of bigger group called Saint-Gobain, which is a global company in the field of construction solutions. The plant in Hyvinkää is producing glass wool, mainly produced from recycled glass cullet. The process was presented more in detail in the chapter 4.4.2.

This visit had both an interview, and a plant tour to get an understanding of what mineral wool is in general: of what does if consist, how it is produced, and what uses it has. The tour around the plant was conducted by two hosts, Hannu Kyckling from the Sales Department and QEHS-manager Janne Vainio.

The interview for the manufacturing phase of Sandwich panels was also part of a plant visit. This visit was done to Ruukki Construction's own plant located in Alajärvi. This visit was done October 7th 2015. The plant in Alajärvi is the place where Ruukki Sandwich panels (product type Sandwich panel SPA) are manufactured. This process diagram was described more in detail in the chapter 4.4.3. The host of the tour was the Head of Safety Mervi Pokela.

The main questions for this interview was the assembly process in general: Which raw materials are needed? How are the panels assembled? Are there possible side streams generating by-products? One point of interest was to see what kind of quality control the plant had: Which tests are being conducted to verify a consistent quality?

The third interview was for the use-phase of the product. It was done on March 15th 2016 at the Finnish Safety and Chemicals Agency (Tukes). Tukes is an agency that supervises and promotes the technical safety and conformity. They supervise products, services and production systems, and enforce the relevant legislation.

During the interview the Head of Unit Heikki Viitala and Senior Officer Kari Siponen from the Product and Installations Surveillance department's Rescue Service Equipment and Construction Products Unit were present answering the questions. The focus of this interview was on the meaning and effects of the CE-marking, which is a compulsory certificate for most of the construction products. The main questions were: What does the CE-marking mean? How it is acquired? How it is controlled? And how does it affect on possibilities of re-using the product?

The interview dealing with aspects of waste treatment was done at the Ministry of the Environment. This was done on September 29th 2015 with Harri Hakaste, Senior Architect of the Department of Building and Construction. During the interview Else Peuranen, Ministerial Advisor of the Environmental Protection Department was also present answering some of the questions. Later, some additional information was sent via email by Mika Vuorikoski, Legal Adviser from the Department of Building and Construction.

The focus of this interview was on the general legislation of waste treatment. Points of interest were: different levels of legislation, difference between professional and private scale, and possible changes in the near future. There were also questions regarding responsibilities and for sources of additional information.

The interview for the recycling phase was at a company called Eko-Expert in Pöytyä. This was again part of a plant tour. The interview was conducted on November 18th 2015. This is currently the only plant in Finland that recycles mineral wool. The host was Kalevi Hirvensalo from Research and Development. He is also the founder of this company and was behind the original idea of this business.

The focus of this interview was to see the current possibilities of recycling the Sandwich panels: What kind of processes are there for this purpose? Is there any large-scale process or only those for private use? And how does the future of this business looks like from his perspective? Other important questions were about the permits needed in this line of business: How do they affect on the business model in general? What are the goals of these regulations? And, are they successful or should there be some changes?

3. Background

This chapter will be presenting the background for the thesis. Since the goal is to find the most sustainable solution which would promote the ideas of circular economy for Ruukki Sandwich panels, some definitions must be presented. First, the concept of circular economy itself will be described. This will be done mostly through EU's plan to adapt this system into society. The second part will be on waste, focusing on legislation and CDW. The third part will be about CE-marking which is a compulsory certificate for most of construction products.

3.1 Circular economy

The currently dominant production cycle is open ended and linear (Andersen 2007). As described in Figure 2, fresh raw materials are gathered and inserted into system where they are processed and refined into products following demand. These products will be in use for their intended life time after which they will become unwanted and turn into useless waste. This is not a balanced system and in time, finite resources will run out. In addition to this losing of materials the increased price volatility and supply chain risks cause disturbances across the system (Ellen MacArthur foundation 2016).

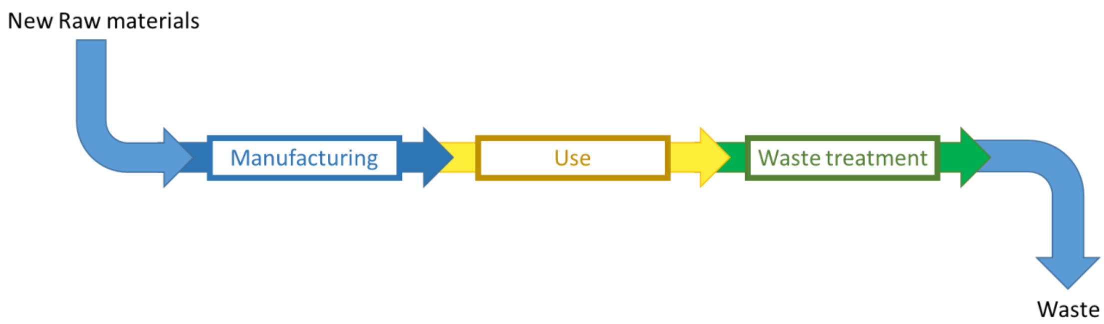

Figure 2: Simplified model of material flows in the current linear, open-ended economy

In this kind of system, which is solely driven by consumption and overlooks restorative use of materials, products are simply discarded at the end of their lifetime and thus, a stream of potentially valuable resources is being continuously lost (Ellen MacArthur foundation 2016). This is not a sustainable way to act in the world with limited resources and constantly increasing economic competition. This is both economically untenable and causes serious environmental damages. Great benefits could be achieved simply by using the already existing resources more efficiently. From the times of industrial revolution the "make-buy-discard" way of thinking has been dominant. This has come along with the false vision that natural resources are everlasting and easily harnessed. Furthermore, this line of thought implies that all waste is easy to dispose. Such a system is currently threatening the competitiveness of Europe, because natural resources are mostly spent making new raw materials that are growing difficult to obtain, while producing vast amounts of waste. (COM/2014/0398)

The problems in global scale will increase steadily as the population grows. It is predicted that the global middle class will double its size to nearly 5 billion by 2030. This grow combined to ever increasing economic growth will empower this trend. A linear economic system has also problems with volatile resource prices and supply disruptions, and more countries are strongly reliant on imports. For example, the EU receives three times more imports than it gives exports (Eurostat 2016). This is because natural raw materials are not spread uniformly across the globe. To overcome such drawbacks more reliable sources of raw materials are in demand. (Ellen MacArthur foundation 2016)

A good solution for this problem is the shift towards a circular economy model. Systems using the model of circular economy have their main goal of keeping the added value of the products as long as possible, while at the same time reducing the amount of waste generated (Ellen MacArthur foundation 2016). Under this scheme, material resources are kept in the system so that, even when a product comes to the end of its operational lifetime, the materials used in its production are used again to manufacture new goods. This keeps the value added to a material, and possibly even increases it through upcycling. This preservation of the added value is one of the primary philosophies of the circular economy and the resource efficiency is the other main principle of this model (Rivero et al. 2016). Evidently, adapting this model requires changes along the current value chain. In principle, this would require modifications in the designing of the products and in their marketing, coupled with technological innovations to efficiently transform waste into useful resources. This isn’t however only a technical problem, as changes in customer preferences, structures of organizations and funding are required. (COM/2014/0398)

3.1.1 The philosophy of Circular economy

Currently, there is no official and complete theoretical definition for circular economy available (George et al. 2015). This thesis will try to give some generally accepted explanation based on the main elements included in this type of model. Some principles and factors that are important in defining the circular economy have been listed. The Ellen MacArthur Foundation has proposed three main principles upon which circular economy should be based on. They are; (i) Preserve and enhance natural capital, (ii) Optimize resource yields, and (iii) Foster system effectiveness. The first one is about dematerializing utilities, which means that they should be delivered virtually, whenever possible. If actual resources are needed, renewable and better performing ones will be favored. The second one means promoting sustainable product design extending product life and optimizing possibilities for re-use. Energy and other value will be preserved by using tighter loops. The third one is about reducing the damages to human utilities such as food, shelter, education and health, and managing external factors such as pollution (Ellen MacArthur foundation 2016).

All the principles presented above act as parts of the greater umbrella term of circular economy. In this thesis however, the focus will remain only on material streams and the loops they are forming. The simplified idea of those material flows in circular economy is presented in Figure 3. This graphical description of the material flows in the system using circular economy is based on the drawings made by Ellen MacArthur foundation, EU and United Nations Environment Programme (UNEP). The figures used in the aforementioned references show how the system works are much more complicated as pictured here, because they have included streams not only for materials but also energy and other parallel circles within the main cycle (Ellen MacArthur foundation 2016). This thesis deal on waste treatment which makes the material streams our focal point.

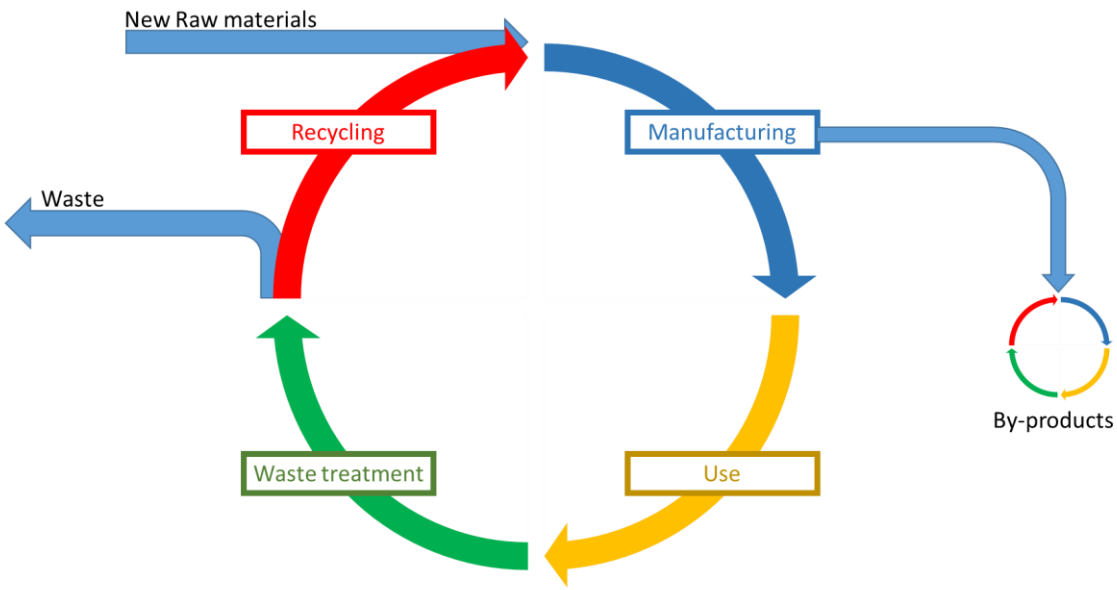

Figure 3: Simplified model of life of a product pictured through material flows in a system using the ideas circular economy.

The life of a product begins from a stream of raw materials. Through manufacturing process, these raw materials are transformed into a product that consumers will use. Manufacturing processes often create simultaneously different by-products which will have their own cycle. This is shown in Figure 3 as a second loop going out from original loop. Consumers use manufactured products as long as their lifetime allows, before discarding it. This disposal is done through waste treatment which may involve several steps, from collecting, sorting to additional processing such as dismantling the product.

Once the product is discarded, it can follow two different routes. The first option is to let used material out from the loop as a stream of useless waste. The second route is to re-insert the material back into the starting point of materials cycle. The latter requires the processing of waste. Nonetheless turning waste into usable resource is the most important thing to achieve in order to get the circular economy model working. (COM/2014/0398)

The ideal case would be that no material would leave the cycle in the form of waste, and that all the material would return to the starting point. This would also alleviate the need for the stream of new raw materials entering the system. However, the ideal situation cannot ever be truly reached, since the fundamental laws of thermodynamics prevent the perfect system (Andersen 2007).

3.1.2 A Zero waste programme for Europe

Adapting the model of circular economy is considered to be a very good solution to economic problems in Europe. The EU has already set some laws and incentives which are planned to encourage different parties towards the model of circular economy. The strongest one probably being the Waste Framework Directive (WFD), and the waste hierarchy within it. The waste hierarchy will be presented in detail in chapter 2.3. For the use of chemicals there is some particular set of rules, but their discussion is beyond the scope of the present work. (COM/2014/0398)

The EU has published a plan for promoting circular economy in its area. This plan is called “Towards a circular economy: A zero waste programme for Europe”. The plan is quite optimistic and it claims to solve the most of current economic problems in the area. The plan states that adopting the model of circular economy would help the scarcity of resources and could increase the weakened demand in the area. Re-using materials and minimizing waste could be a really strong advantage in the markets giving the European companies a reliable flow of raw materials while others would struggle with diminishing natural resources. The EU’s plan is to greatly reduce the amount of waste generated, while using it as a major source of resources. The economic viability is the prerequisite for sustaining this kind of model. This could also help alleviate the problem of unemployment in the area, by promoting the “re-industrialization” of Europe. Further identified advantages are the reduction of greenhouse gas emissions and the improvement of energy efficiency, while securing the availability of raw materials. (COM/2014/0398)

In industrial manufacturing processes, some benefits of the circular economy model are already identified. The studies concluded by the EU (Ellen MacArthur foundation 2012) suggest that, by increasing the material efficiency, it would be possible to reduce the need for new raw materials by one fifth by the year 2030. The same study also suggests that the industry could make savings of up to 630 billion euros. The Gross domestic product (GDP) of the EU area could possibly even increase by 3.9% with new market potential (COM/2014/0398). However, it is expected that a transition to a circular economy cannot happen seamlessly without problems. Many companies that want to take this road will face uncertainties, perhaps the greatest being that at the moment it seems more economical the prices of natural resources are lower than those recycled (Andersen 2007).

Due to the impending scarcity of raw materials, it is very likely that waste will be considered to be a valuable resource in the future, which is one of the main justifications of circular economy. If the "cycle" of circular economy is to be effectively closed, and the loss of material resources minimized, waste streams will have to be repurposed as raw materials for new products. The EU is trying to improve waste treating with its guiding legislation. The EU is also trying to encourage companies to take up responsibilities in the collecting and recycling of waste and make new innovations that will speed up such process. The goal is to reduce the amount of waste ending up in a landfill to almost zero, thus minimizing the waste of resources and changing customer's habits. (COM/2014/0398)

In our capitalistic system, recycling will be undertaken at industrial scale, only if it there would be profits available (Andersen 2007). It is therefore important to set a framework to support companies adapting to the circular economy model. Naturally, the markets are currently the main driving force for change. Raw materials and energy are main expenditures for the most companies which means that a possibility to obtain savings on them can be a real incentive. The EU's plan states that reducing waste, promoting eco-design and re-using materials can bring considerable savings. These actions could also create new branches of industry in a form of new companies in the field of recycling and designing. Often, established companies find it hard to take on big changes like this as they have an existing business models, old technology and their own culture which have provided until now an acceptable level of security. Change, on the other hand is perceived to bring uncertainty. If a new model is to be adopted successfully, re-education to form new ways of thinking are needed. Investors must be shown that benefits can be obtained if the change is successfully implemented, in the short, mid and long term. (COM/2014/0398)

Careful planning and technological innovations are needed for implementing a model of circular economy (Lieder et al. 2016). These innovations are needed along the whole value-adding chain and not only at the end. The following list shows a series of current issues that require to be solved:

- Decrease the amount of material needed in manufacturing the product or service
- Extend the life of the product
- Decrease the energy needed for manufacturing the product
- Reduce the use of hazardous materials
- Create the markets for recycled materials

- Design products that are easier to maintain, repair and recycle. (The so-called eco-design)
- Create the needed services to support all this
- Encourage the customers to reduce the amount of waste while increasing the sorting of waste
- Encourage parties responsible of collecting and sorting waste in order to get costs of recycling lower
- Assess the benefits of centralism, which makes it easier to utilize the side streams and by products of materials processing
- Utilize the new service models such as renting, borrowing and sharing of products

Some actions to increase the attractiveness of the circular economy are needed, because change in this scale does not happen on its own. Encouragement through financial means is evidently the most effective way. In the case of the investors, there could be some risk reduction, for example a public-private partnership (PPP), because they could help the private sector using resources more efficiently. The public sector could guide the way by easing taxation, for example by shifting the focus from the labor to environmental factors and efficient use of resources. The companies and customers are the most important parties in the transformation to circular economy. Decisions and discussion should go into both ways so the opinions of each side could be heard. The producers, investors, distributors, consumers and recyclers are all important parts in this system. Also the markets have a huge influence. Bottle necks and other problematic parts should be identified and fixed. Markets for the recycled material should be created and the entry of new companies in this industry sector should be made easier. This has to be taken in consideration also in the training and education of human capital so that suitable workforce would be available. Finally, information should be given to the consumers so that they could make more sustainable choices. (COM/2014/0398)

In the production, it has been suggested that the focus should be on effective outsourcing, voluntary changes for both the companies and retailed to form possible industrial symbiosis to utilize the side streams. In the distribution of goods there should be also information included about the material composition of the product and instructions how to maintain or recycle it. There could also be a possibility to introduce a product pass that has information and recommendations for the product. For consumers there are many different business models that could be used to reduce waste such as borrowing, swapping and renting the item resulting in a more efficient use of resources. In larger scale, this could be run by the public sector. (COM/2014/0398)

To monitor the development towards a sustainable, circular economy model, some kind of metrics are needed. Introducing a measureable environmental footprint would be an effective way to get the overall picture of the burden caused by the product. This could be a clear metric since it shows the environmental impact of a product as a result of manufacturing and use. A parameter based on environmental footprint would help customers make more environmentally friendly choices. A clear framework would however be required to clarify the meaning and structures of the new system. A continuous evaluation system would motivate producers to improve their products in order to obtain a better rating under this evaluation scheme. Local authorities would have the responsibility of controlling the adequate implementation of this metric. (COM/2014/0398)

A properly implemented circular economy model would result in having only non-recyclable material used as fuel for energy production. From an economical point of view, the reason for this whole system in the EU is to stimulate economic growth, create new jobs, and increase the competitiveness of the area, while at the same time taking care of the environment. The EU’s plan states that if the implementation were successful, it could create 180,000 new jobs directly and 400,000 indirectly by the year 2030. The recycled material would also provide to up 10 – 40% of the need for raw materials in the EU area. (COM/2014/0398)

3.1.3 Challenges to achieve an efficient recycling society

A change in this scale cannot be implemented easily. There are, for example, considerable differences between the practices in waste treatment in the EU member states. Some countries have decreased the amount of waste that ends up in the landfills from 90% to 5% in only 20 years. In some areas, 85% of municipal waste is being recycled. On the other hand, in some places 90% of the waste still ends up at the landfill and only 5% is recycled. (COM/2014/0398)

Effective and clear paths for the development of markets based upon recycled materials should be arranged. This is however currently pursued only by setting goals on amounts of recycled materials for the year 2030. The EU should provide clear signals for investors that markets are being created, and encourage them to make new investments for the industry. In this way, the development of systems supporting the circular economy could be started well before the complete depletion of raw materials sources. Taking potentially recyclable material to the landfills is being ceased by the year 2025 and landfilling nearly every other waste by the year 2030. Using waste as fuel for energy production is a very important point in this model, as nearly all of non-recyclable is supposed to be burned or otherwise used as energy source. Education and training must mainly be given to areas that have no previous experience in such activity in order to avoid the know-how from accumulating into one place. (COM/2014/0398)

The EU has established goals and metrics to be pursued while steering to more sustainable direction:

- The level of re-use and recycle of community waste must be increased to 70 percent by the year 2030
- Recycling of packaging material will be gradually increased to 80% by the year 2030 as follows: 60% by the year 2020 and 70% by the year 2025
- Ban the landfilling recyclable plastics, metals, glass, paper, cardboard and organic waste by the year 2025: Other types of waste will follow by the year 2030 (COM/2014/0398)

This should support the development of markets for high class recycled materials. Clear deadlines would encourage companies to invest in this kind of business well in advance which should improve the quality of recycled material.

In order to get a transformation of this scale completed, a lot of changes in the legislation and other rules are needed. The EU has set its framework so that the member states can decide themselves how they are going to fulfill the needed goals, allowing each country to implement their own legislation as they see fit. In the year 2012, the EU Commission developed the metrics for waste treatment along with guidelines for the member states in the weakest position regarding their waste treatment and recycling level. The Commission focused on countries who still had a long way to go in order to reach the desired regulatory levels. Ideally, it was developed to acknowledge their problems right from the beginning. (COM/2014/0398)

Regarding the commitment from the private sector, companies could be guided towards recycling model with taxations. One suggestion is to introduce e.g. taxes for landfilling, for burning recyclable waste, pay-as-you-throw-tax, and increase the responsibilities given to the producer. This would encourage companies to re-use and recycle instead of landfilling (COM/2014/0398). Especially the bans of landfilling are proven to be effective and the volume of waste ending up in landfills is decreasing (Eurostat 2016b). The EU is planning to cease the subsidies it has been giving for the maintenance of the landfills and incinerators completely. Funds are rather directed to actions supporting circular economy and its development. Legislation about waste transportation should also be made easier, so that the waste could be collected and transported to processing plants using the best available technology (BAT) without restrictions. (COM/2014/0398)

3.2 Waste

As it was presented in the previous chapter, the main issues with the model of circular economy compared to the current practices are streams of material and energy leaking out of the system. The most significant of these streams are waste streams. With them a significant amount of raw materials is being lost from the system generating the growing need for new material. Often this leaving material is treated in a way that makes it unusable even in the future preventing any viable recovery options. Because of this, it should be advised to find a way to minimize outgoing waste streams.

3.2.1 Definition of waste

Everyone has an opinion on what waste is, but a clear definition may vary depending on the consulted source. Consequently, it is important to know the official definitions for various materials and substances of interest to avoid any misconceptions. This is especially important when talking about legislation, because laws must be unambiguous and very clear. The Finnish law (Finnish Waste Act (646/11)) and the Waste Framework Directive (WFD) (Directive 2008/98/EC) of the European Union both use the same definition for waste. The definition of waste according to the law is very important because it is directly referred to in legislative work, and is used as basis to set the rules of waste treatment. For example, the EU's REACH-regulation for the use of chemicals does not define waste in the same way that WFD does, and hence it cannot be applied the same way (The European Union 2016a).

The definition for waste according to WFD and the Finnish law is the following:

"Waste means any substance or object that the holder discards, intends to discard or is required to discard." (2008/98/EC, Finnish Waste Act (646/11))

This is the universal definition and it covers all different types and classes of waste. Also the word "discard" mentioned in this definition must be defined carefully to avoid any misunderstandings. The definition of waste can be divided into three sub-statements where the word “discard” is used, namely: (i) discarding presently, (ii) intention to discard and (iii) requirement to discard. None of these exactly clarifies however what “discarding” actually means. Clarification for the concept of discarding is provided by the Court of Justice of the European Union (CJEU) and it goes as following:

“The term discard applies to both recovery and disposal of waste. However, it should be noted that this does not mean that any substance which undergoes a recovery or disposal operation as listed in the WFD annexes is waste per se, but it might be regarded as evidence for being waste.” (The European Union 2016a)

The definition of discard has again two new terms that must be defined. They are recovery and disposal and they include all the possible actions of waste treatment.

“Recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.” (2008/98/EC)

This means that the waste receiving recovery operations can be used in a useful process which would otherwise require some other material or substance to be completed. This includes uses both as raw material and as fuel for energy production. Examples of recovery operations could be recycling of metals or solvent regeneration. All the different possibilities for recovery operations acknowledged by law can be found in the Annex II of the WFD, which can be found as Appendix 5 in the end of this thesis.

”Disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.” (2008/98/EC)

This means that all the waste treatment processes that do not fall under the definition of “recovery” are considered to be “disposal” operations. Disposal processes do not produce usable substances or energy which makes them non-sustainable choices to be avoided. Examples of disposal operation could be landfilling or some other form of substance storage. All the different possibilities for disposal operations can be found in the Annex I of the WFD, which can be found as Appendix 4 in the end of this thesis.

Discarding can involve a positive, neutral or negative commercial value. From its definition, no distinction is made based on whether the substance or object is marketable or not. Discarding can also be intentional or deliberate by the holder, can be unintentional/involuntary/accidental, or could even occur with or without the knowledge of the holder. If a company transfers material to a waste collector, it is considered to have been discarded (The European Union 2016a).

It is also worth defining the term “by-product” as a potential status for a material or substance. A by-product is not the substance originally wanted, but it is also not waste. (The European Union 2016a) WFD gives the official definition and criteria to be fulfilled for by-product. This is also used under Finnish law and is the following:

- Further use of the material or substance is certain
- The material or substance can be used directly without any further processing other than normal industrial practice
- The material or substance is produced as an integral part of a production process
- Further use of the material or substance is lawful and it fulfills all the requirements for its specific use (Finnish Waste Act (646/11))

Taking a closer look to what is needed for a material or substance to be considered as by-product instead of waste; the WFD offers the following detailed criteria that must be fulfilled to gain the status of by-product.

- Further use of the substance or object is certain. This means that it has to be completely certain and not just a possibility. This can be proved, for example, by showing an existing contract between the producer and the future user of the material, by showing that there is an active market and demand for this certain material or that there are economically viable ways to process it.
- The substance or material can be used directly without any further processing than normal industrial practice. (e.g., shaping or cutting). Other minor operations like washing, drying, separation or addition of other materials are accepted, but not any other kind of processing.
- The material or substance must be produced as an integral part of a production process. If it is taken away from the plant it has been manufactured into another plant for further processing it will lose its status of by-product.
- Further use of the material must be legitimate and it hast to fulfill all relevant product, environmental and health protection requirements for its specific use and not lead to overall adverse environmental or human health impacts.

Every single one of these conditions must be met for a substance or material to be regarded as by-product and not waste. (The European Union 2016a)

By definition, it follows that every substance and material is either waste or non-waste. This division is absolute and there are not exceptions like “partial waste”. On the other hand materials and substances can cease being waste if certain criteria are fulfilled. The storage location of a material, for example does not influence whether it is considered to be waste or not. An example for this could be the case where a company stores its materials at a landfilling site. As long as this material is not intended to be discarded it is not considered to be waste. Figure 4 shows in a schematic fashion the EU’s Guidelines on the interpretation of key provisions of Directive 2008/98/EC on waste to determine whether a substance is waste or not.

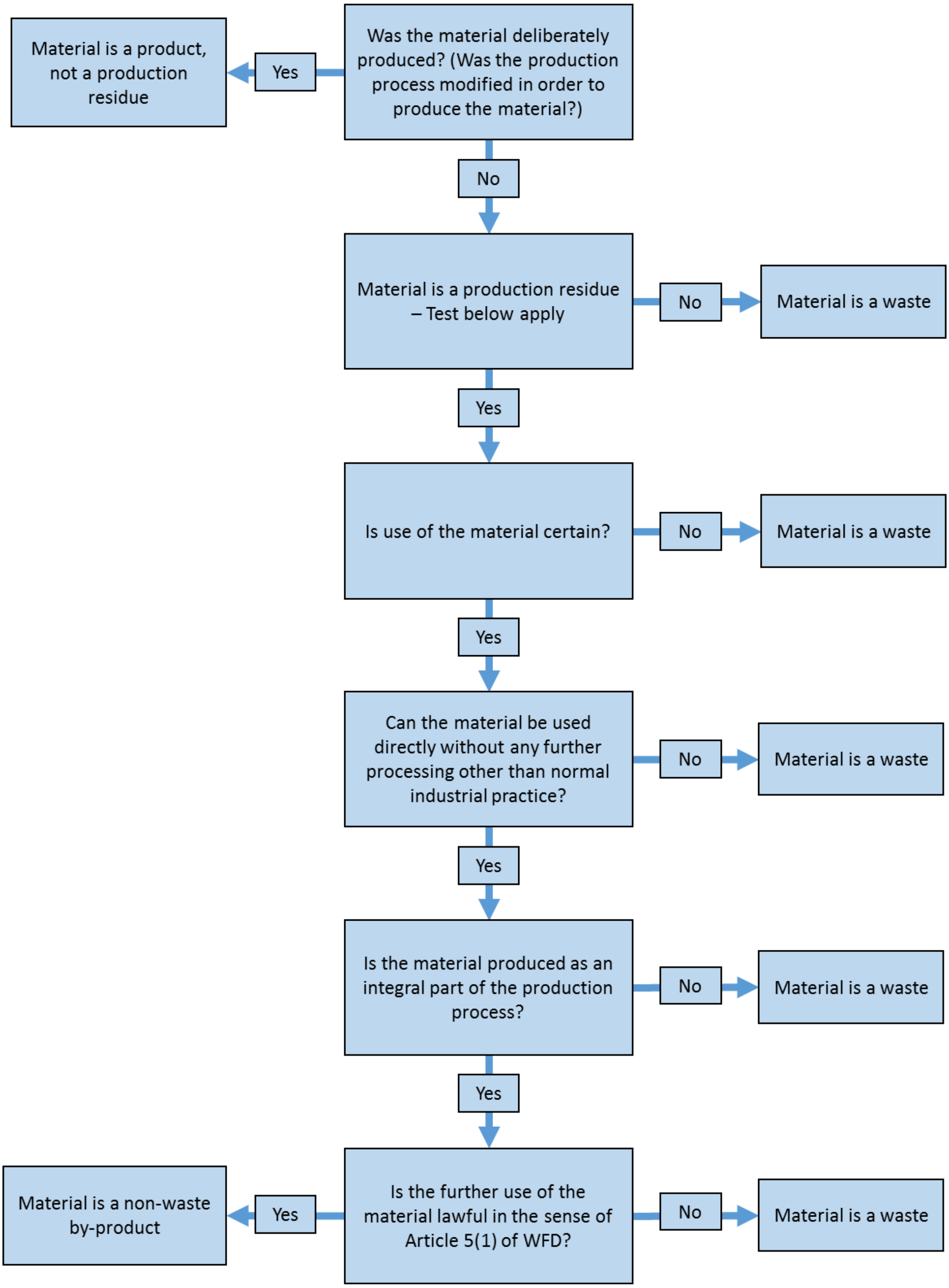

Figure 4: A decision diagram instructing whether a material or substance is waste or by-product. (The European Union 2016a)

As mentioned before, the status of “waste” may not be permanent. When a material with status of waste undergoes recovery, including recycling operations, it may cease being so and gain the end-of-waste (EoW) status. Once a material is no longer classified as waste, and a different set of rules will be applied to it. The law provides a specific set of conditions that have to be fulfilled in order to acquire the EoW. The EoW criteria presented in WFD are following:

- The material or substance must be commonly used for specific purposes
- There must be a market or demand for this certain type of material or substance
- The substance or material must fulfill the technical requirements for the specific purposes and it meets the existing legislation and standards applicable to products
- The use of the substance or material will not lead to overall adverse environmental or human health impacts.

It should be noted that all the criteria above must be fulfilled to gain this EoW status. (The European Union 2016a)

Under Finnish law, there is also mention of when waste ceases to be classified as such. This happens when the material has (i) undergone some recovery processes, (ii) it has found some use, markets and demand and (iii) it fulfills the necessary technical requirements (Finnish Waste Act (646/11)). As seen, these are in principle the same criteria used by WFD.

3.2.2 Construction and Demolition Waste (CDW)

CDW consists of everything that falls under the above-described category of waste and results from construction, repair and demolition activities (The European Union 2016c). The category of CDW is much larger than just what comes out of defined construction products, which are defined differently (Tukes 2016). CDW does not only come from constructing buildings but also from road construction, land leveling and dredging, for example. This causes many misunderstandings and incompatibility in published statistics because there are different definitions even in the EU area, and while countries count materials from land leveling, others do not. This makes the comparison of generated volumes challenging. (The European Union 2016c)

CDW is one of the largest streams of waste in the EU; accounting for ca. 25 – 30% of the total waste generated and is considered to be one of the priority streams of the EU area. One reason for this special status is that it has a very high recycling potential. Several materials obtained from CDW have real commercial value and already having existing markets. In particular, materials from land leveling have large markets and demand. (The European Union 2016c)

This CDW category is very heterogeneous, spanning a very broad range of different materials such as concrete, bricks, gypsum, timber, glass, metals, plastics, solvents, asbestos and soil. It has been claimed that many of these materials could be recycled more efficiently than is being done using current strategies (Kyckling and Vainio 2015, Metallinjalostajat ry. 2014). The main problem to recycle this type of stream is that all these different materials are mixed, and sometimes even bound with each other. Consequently, the various components need to undergo separation processes if they are to be sold. Evidently, the implementation of such separation process costs money and requires additional resources and investments. Currently, there are separation processes that can be applied to CDW and new ones are continuously being researched (Hirvensalo 2016).

3.2.2.1 CDW in Finland

The latest data from Statistics Finland about the CDW volumes was produced in 2013. The total amount of CDW in Finland at the time of the report was 15.1 million tons, being nearly one sixth of all the waste generated in the country (96.2 Mt) (Statistics of Finland 2013). In statistics from the year 2011, there were 18.4 Mt of CDW. Not accounting for the waste from land leveling and dredging, the amount of CDW was 2.2 million tons which shows that the major volume of CDW is in fact waste from soil construction. Approximately 1.8% of this was hazardous waste. (Statistics Finland 2011)

In Figure 5, the division of waste per sector in Finland from the year 2013 is shown. It can be seen that mining industry is producing the largest amounts of waste. CDW is the second largest. In Finland nearly 70% of total waste generated comes from mining industry. This includes unrefined natural resources from mines and earthworks, but also bricks and concrete which are part of CDW. Because the current limitations of recycling and the large volumes of mineral waste generated the total recovery of waste in Finland was close to 16%. (Statistics of Finland 2013)

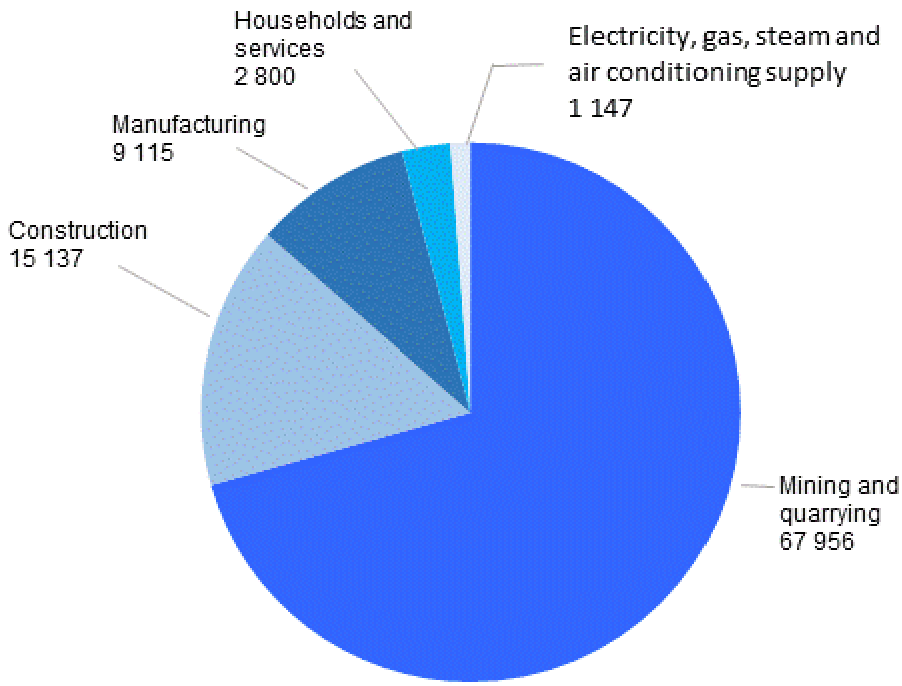

Figure 5: Distribution of waste amounts per sector in 2013, 1000 tons. (Statistics of Finland 2013)

In the EU area, CDW represents about one third of the total waste generated. This equals about 500 million tons of waste per year, out of which 46% is being recycled. In Finland, only 26% is recycled. However, these numbers should be viewed with caution. This is because, even in the EU area, the information is spread widely among many different parties, which makes assessing the overall situation difficult. Statistics may vary significantly among the EU member states because each has their own methods of collecting and reporting data. Because the volumes of CDW are a significant slice of total waste generated, EU has special limits set by the WFD stating that the goal is to get 70% of CDW generated to be recycled by the year 2020. Some countries such as the Netherlands and Denmark have already even exceeded this target with a recycling level of 90%. (The Ministry of Environment 2013)

The composition of the CDW has big differences among the EU member states. This can be attributed to several factors, ranging from their current economic situation and, cultural factors. As mentioned before, there are also different ways of keeping statistics. The quality of CDW is affected, for example, by the age of the buildings, the methods and materials used in the construction, primary materials used and historical values of the buildings. In Finland the composition of CDW is shown in Figure 6 and it has the following division: 41% of waste is wooden material, 33% of waste is rock and mineral-based substances such as bricks and concrete, and 14% is metal scrap.

The large amounts of wooden material bring also difficulties in Finland. Wooden material cannot be easily recycled and its re-using possibilities are limited in general. The most common discarding method for wood is through energy recovery, meaning it is burned to produce heat. This is an efficient way to discard it, but the material itself is lost. This brings down the recycling level of CDW in Finland, because statistics do not consider energy recovery as a recycling method. In southern and central Europe, the composition is very different having for example only 5% wood. (The Ministry of Environment 2013)

57% of the total CDW is generated by repairing work, 27% comes from demolition and only 16% from new construction as illustrated at the right-hand side chart in the Figure 6.

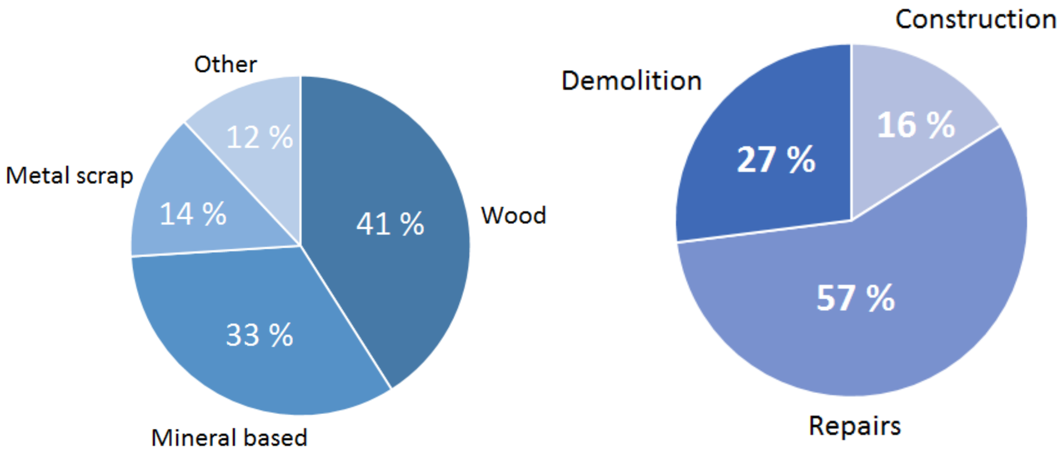

Figure 6: CDW composition, (left) and sources of CDW by operation (right) in Finland. (The Ministry of Environment 2013)

These three different phases of construction will all produce waste differently. The volumes of waste from constructing of brand new buildings can best be minimized by reducing the need of building new structures in general. This can be achieved through design, aiming at having long life times, and being easy to maintain and repair. It should also include possibilities for flexible use so that the structure doesn't lose its purpose so quickly. Attention should also be paid to material choices to make sure they promote re-using and recycling. The repair and maintaining phase requires mainly spreading information on how and when to perform maintenance. This applies also on the demolition phase: the demolition contractor must be informed on how to disassemble the building without damaging components that can be re-used, and how to do the sorting of materials. (The Ministry of Environment 2013)

3.2.2.2 Trends

Predicting the future trends for the CDW is really difficult. Suitable and comparable data needed for the modelling is hard to obtain because the information is collected and distributed by many different authorities and government bodies. Often, these pieces of information are not as accurate as they should be for credible conclusions (Kourmpanis et al. 2008). Volumes of CDW are highly dependent on the ongoing business cycle, which means it is very fluctuating.

A more general trend for sources of CDW in some geographical areas is to shift the focus from constructing new buildings to repairing of existing ones which may change the composition of CDW. This is mainly because the buildings built in the post war era are now reaching the point where some major repairs must be made. It is also estimated that the volumes of CDW are likely to increase in the future because the buildings constructed after the war require renovation and repair to meet tightened energy regulations. (The Ministry of Environment 2013)

3.3 Waste hierarchy

The goal of the EU WFD is to guide the member states towards a more efficient use of resources, often termed as “material efficiency”. In addition to this, the directive also proposes strategies to reduce the harmful impacts of waste on the environment and human health (The European Union 2016c). In this context, “material efficiency” refers to means and principles aimed at reducing the amount of waste generated. “Material efficiency” is part of broader concept of “resource efficiency”, which goes beneath the term “eco-efficiency”. The material-efficient actions reduce the use of nonrenewable resources, reduce the amount of generated waste and encourage recycling of materials instead of wasting them. From this perspective it may be possible to minimize waste generation while gaining significant economic benefits and savings. (The Ministry of Environment 2013) Simply put, the resource efficiency means producing more with fewer resources used.

The EU's waste hierarchy is presented in the WFD. This hierarchy shows in which order the different waste treatment possibilities should be favored. The Hierarchy is intended as the main guideline for waste treatment in the EU area and as a basis for regulations dealing with waste (2008/98/EC). Accordingly, the Finnish law uses the same hierarchical system (Finnish Waste Act (646/11)). The different levels of the hierarchy, starting from the most recommended approach at the top, can be seen in Figure 7.

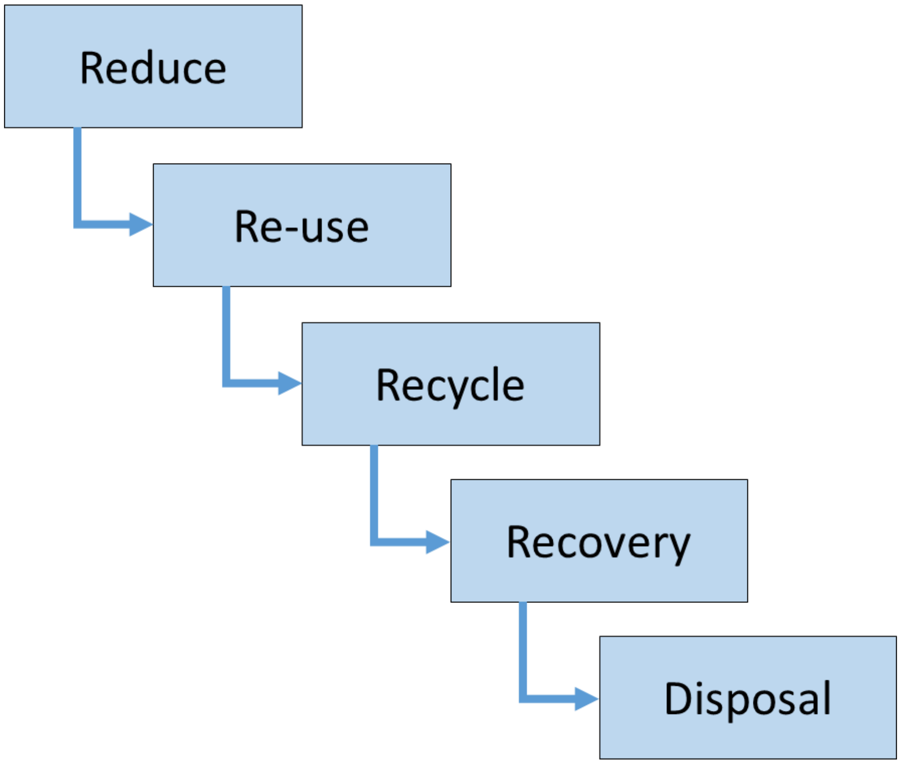

Figure 7: Steps of WFD waste hierarchy, from most favorable (top) to least favorable (bottom).

The ways of reducing the amount of generated waste can be for example, increasing the possibilities for re-using, lengthening the life cycle of the product, reducing possible health risks for example by avoiding usage of hazardous materials. Reducing the waste generation is not a waste treatment method as such, since it is supposed to act upon objects and substances before they become waste. In short it said that preventive methods are measures that are taken before a material or substance becomes waste (The European Union 2016a). Below are some examples of such methods:

- Spreading the information about benefits of the material efficient production and research about resources savings.
- Voluntary contracts between consumers and manufacturers to acquire metrics about efficient use of materials and levels of re-use.
- Programs aimed at protecting the environment by encouraging the local parties to impact of their activities.
- Subsidies and other economic incentives to guide the development to the desired direction.
- Substituting hazardous materials with less hazardous or completely non-hazardous alternatives. (The European Union 2016a)

The second level is re-using the material (2008/98/EC). This means using the product or parts of it again after its originally intended use to a same kind of purpose. Re-using is not actually a waste management operation, since it increases the life of a product by preventing it from becoming waste, thus making it essentially a preventive method. (The European Union 2016a)

When a product is being prepared for re-use, some operations may be required, in which case, these also fall under the category of re-using. Such preparing operations can include checking, cleaning, and minor repairs. The difference between preparing for re-using and re-use is that in the latter case the product has never been defined as waste and it can be used as it is without any treatments. (The European Union 2016a)

The third category is recycling of material (2008/98/EC). The term recycling consists of different recovery operations, in which used materials are being processed into products or raw-materials either for their original purposes or completely new ones (The European Union 2016a). This includes the processing of organic matter, but not using it as a fuel or some other energy source (2008/98/EC). Recycling includes any physical, chemical or biological treatment that results in material no longer being classified as waste. It is not exactly stated in the WFD which processes should be used, but as long as the objective is to generate raw materials which can be used for its original or other purposes closing the economic material circle, it is considered recycling. The material must have a purpose, meaning that processes intended at only changing the nature of waste, for example by making it less hazardous, are not recycling. These kind of operations can be classified to be preparation for recovery or preparation for disposal. (The European Union 2016a)

The fourth step in the waste hierarchy is recovery (2008/98/EC) or “other recovery”. This includes all other recovery operations except recycling which can be considered as recovery of materials. Operations falling under this category can be, for example, recovery of energy through incineration. Using the waste as fuel is also considered to be a form of “other recovery”. (The European Union 2016a)

The last and the least favorable of the steps is disposal (2008/98/EC). Roughly this category has all the operations which do not belong to any preceding ones. They do not fulfill the criteria of recovery operations. Examples of these could be, for example, incineration without energy recovery or perhaps the most popular one: landfilling. This applies even if a landfilling site is used for energy generation through gas collecting. (The European Union 2016a)

3.4 CE Marking

All the products sold in the European Economic area (EEA) are assessed to meet high safety, human health and environmental protection requirements. To get all the goods in the market area to meet these set levels, a framework for operations is needed. A system like this supports fair competition by holding all companies accountable to the same rules. To achieve this, there is the CE-marking (The European Union 2016b). A picture of the CE-marking is shown below in Figure 8.

Figure 8: The official CE-marking. (The European Union 2015)

By branding a product with the CE marking, a manufacturer assures that their product meets all the legal requirements and it can be sold throughout the EEA. This also applies to products made in other countries that are sold in the EEA. Although the CE-marking will not point out the origin of the product, it sets the domestic and imported goods on a same level by pointing the need for equal properties for safety. (The European Union 2016b)

The CE-marking intends to bring two major benefits for the businesses and consumers within the EEA.

- Businesses can trust that products with CE-branding can be traded in the EEA without any restrictions or customs.
- Consumers can trust that with CE-marked products they receive the same level of health, safety and environmental protection in the entire EEA. (The European Union 2016b)

In general, not all the products need to have CE-marking. It is only needed for products covered by the New Approach Directives. Other products cannot have it and it is forbidden to attach the marking on the products that do not fall under that category. (The European Union 2016b)

The Finnish Safety and Chemical Agency (Tukes) supervises and promotes the general technical safety and conformity in Finland. They supervise products, services, production systems, and enforce the relevant legislation. The aim is to protect people, property and the environment from any safety risks. They are also the main surveillance authority for construction products in Finland. This includes the monitoring of CE-marking. (Tukes 2016)

3.4.1 CE-Marking in construction products

A Construction product is by definition an object which is intended to become a permanent component of a building or structure (Tukes 2014). However, material used during construction work on the construction site but removed after the construction process is complete is not considered to be construction product (Tukes 2016). These can be for example concrete elements, windows, steel structures and timber. Construction products have to be suitable for its intended use especially in the field of safety and it must be able to fulfill its purpose for its whole intended lifetime. Lifetime of a construction product must be economically reasonable (Regulation (EU) No. 305/2011).

In general, all the construction products need the CE marking. CE-Marking has been mandatory for construction products since 1.7.2013. This means that no products without this marking have been allowed in the markets within EEA after this date (Regulation (EU) No. 305/2011). There are some exceptions, however. Marking is not needed if the construction product is other than a mass produced product and the manufacturer of the product is responsible of installing it in construction works. Another case is that the construction product is manufactured on the construction site itself or it is manufactured in a non-industrial process to be used for renovating protected buildings or heritage conservation. (Tukes 2014)

The CE-marking for construction products must not be mistaken to have same meaning as, for example, the one for electrical appliances. For construction products, the marking does not guarantee good quality and safety as it does for other products and it is mainly to provide information. The CE-marking itself is a certificate that shows that the product has completed a long process of standardized tests and has all the compulsory information attached. (Viitala and Siponen 2016)

By attaching the CE-marking, the producer assures that the construction product has the appropriate technical properties set and accepted by the Harmonized European Standard for a Construction Product (hEN) and the European Technical Assessment (ETA). This shows that all the needed tests have been performed to determine that the product is suitable for its intended use. The mark can be earned by passing a test done to a single property at minimum.

The marking is compulsory for all the construction products that have the Harmonized production standard. hEN is the leading standard set by European standardization organization CEN leading to the CE-marking. Manufacturers of construction products are responsible of finding out whether the product falls under this category thus needing the marking. If a product does not have a harmonized production standard it is not required to have CE-marking. These standards can be found from the Finnish Standard Association (SFS).

3.4.2 Acquiring process of the CE-marking

To acquire the CE-marking for a product, a manufacturer has different tasks to complete. The first step is to identify the construction product and its possible intended uses. Then the manufacturer has to check whether the product is on the list of hEN. If it is, the CEN-route has to be followed. The next task is to identify the essential characteristics and assessment and verification of constancy of performance (AVCP) system for them. For each of these characteristics of the product a certain performance level has to be declared. This is done through testing and tabulated values with appropriate AVCP systems. The essential characteristics may be under a different AVCP system depending on their intended use. For the production, this means that controls have to be implemented to prevent production performance changing over time. In this manner, it is indirectly assumed that the quality of products will remain the same. (The European Union 2015)

After all the needed information is gathered and the obligatory testing done, all the background documents must be collected. These are, for example, test results and values, documented factory production control procedures, certificates from the notified bodies if needed, and appropriate technical documentation. The declaration of performance (DoP) must be translated to the languages required by the member states where the product is being sold. The next step is attaching the CE-marking itself. This is done along with the addition of instructions and safety information for the product. All these requirements and other background information like the DoP need to be stored for ten years from the last time this product was sold. Additional measures need to be taken, if the product is in the scope of REACH regulation. After all this is done, the product is ready for markets. However, if the performance, raw materials or the manufacturing process change or hEN is significantly revised, the procedure has to be repeated. (The European Union 2015)

There are four documents to be provided to the customer. They are DoP of the product, CE-marking and accompanying information of the product, Instructions and safety information, and REACH information if required. The most important one of these CE-marking supporting documents is the DoP. In short, DoP contains the full information about the manufacturer, the product and its performance, whereas the CE-marking itself is just a summary of these (The European Union 2015).

The following list shows the complete information included in a DoP:

- The number of DoP
- Unique identification code of the product type
- Intended use/uses
- Manufacturer
- Authorized representative
- System/s of AVCP
- Harmonized standard and Notified bodies, or European Assessment Document, European Technical Assessment, Technical Assessment Body, and Notified bodies
- Declared performance

- Appropriate Technical Documentation and/or Specific Technical Documentation
- Link to the online copy of the DoP (The European Union 2015)

The goal is to improve the possibilities to compare the properties of different construction products, and to create a single effective and functional market for construction products in the EU area (Tukes 2016). Designers and consumers can compare the products and their declarations of performance more easily if every producer is offering the same information. It is important that the same information is available for every product and that it is presented in a similar way. This will also ease, for example, the Finnish products in EEA. A construction product with CE-marking can be brought into the markets of every EU member state without specific statements that would otherwise be required to be done in each country separately. Nonetheless, for the use of the construction product, there may still exist national provisions in practice, e.g. on the use of construction product as an installed system, and to manage such may require additional country-specific actions.

As it was stated, the CE-marking by itself is not a guarantee of good quality or that it is suitable for certain uses. Evaluation of whether the certain products can be used in certain purpose or end use, conditions at the construction site or the demands set by the building control must be done for each case separately.

That being said, the summary of the benefits gained from the CE-marking for construction products is following:

- Makes comparing the properties of construction products easier and helps choosing the best one available (Tukes 2016).
- All the crucial information and needed properties will be shown in a uniform European way
- A product with CE-marking can be brought into the markets of EEA without any testing in each country separately

4. Case Study

In this thesis, Sandwich panel by Ruukki Construction will be used as a case example of the problems concerning re-using and recycling of the construction and demolition waste. This is a particularly fitting example, since, due to the physical characteristics of the panel, there are different options for waste treatment throughout the various steps of the waste hierarchy. The most important one for promoting the circular economy being the possibility to either recycle or and re-use of the product after its initial life.

In this chapter, a description and intended use of the product will be presented first, followed by a detailed description of their materials of construction and structural design. After this, the current manufacturing process will be presented, starting with the different panel components and finalizing with the assembly of the panels itself. The information shown here is based on the information made public at Ruukki Construction's official webpage and supplemented with visits done to the actual manufacturing sites.

4.1 Description of the product

The Sandwich panel consists of two coated-steel sheets that have insulating layer of mineral wool glued in between them. This mineral wool is either made of glass or stone. There are different types of panels with different thicknesses but the main principle is the same. Thickness of the Ruukki's Sandwich panel SPA has range from 80 to 230 millimeters (Ruukki Construction 2016a). There are also different surface profiles available. Possibilities range from entirely smooth surface to dense grooving, which will provide different shading onto walls. These surface profiles are mainly for architectural reasons (Ruukki Construction 2016b). Three examples of surface profiling can be seen in Figure 9.

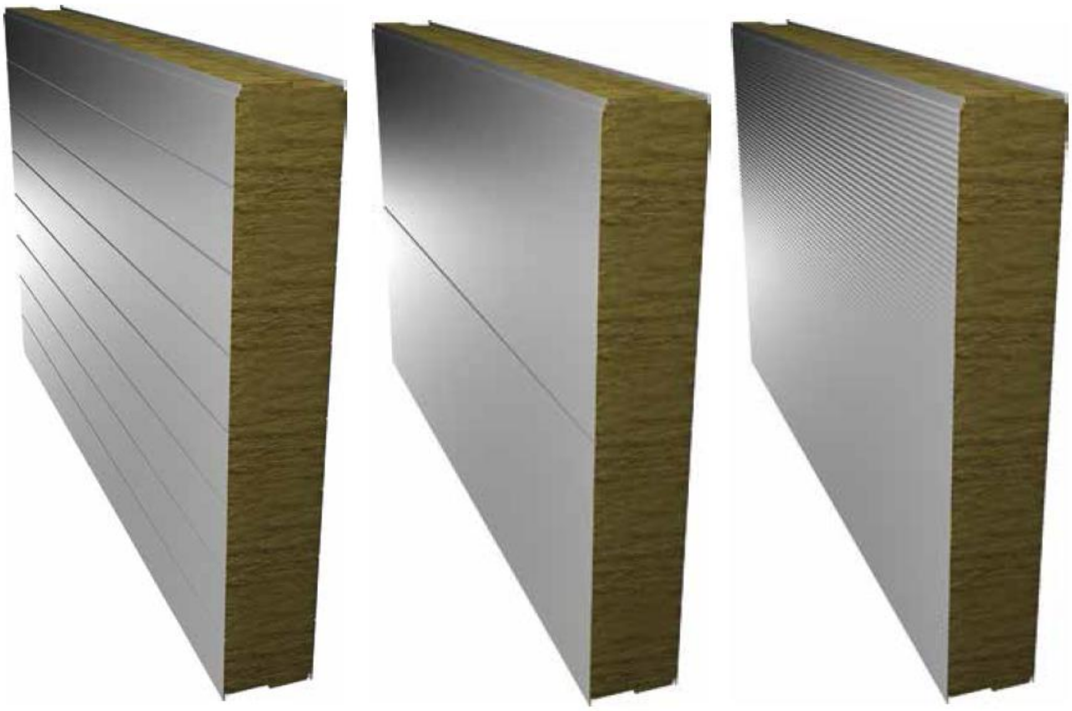

Figure 9: Examples of different surface profiles for Ruukki Sandwich panels (Ruukki Construction 2016b).

4.2 Usage

Ruukki's Sandwich panel is a prefabricated element that can be used in facades, partition walls and ceilings. Typical applications are industrial buildings, warehouses, office and commercial buildings and other hall type of buildings such as sports halls. Figure 10 shows a picture of a finished hall made of Sandwich panels. Furthermore, if proper coatings are applied, it is possible to use these panels in food processing plants and other high demand applications. Sandwich panels give both good sound and thermal insulation. They are also highly fire resistant which means they can be used as fire-separating structures. (Ruukki Construction 2016a)

Figure 10: A hall with facades made of Ruukki Sandwich panels

Using Sandwich panels can help to get the Leadership in Energy & Environmental Design (LEED) and BRE Environmental Assessment Method (BREEAM) certificates for the building. These are known certificates by certain independent parties which promote and assess the sustainability of buildings (LEED 2016, BREEAM 2016). Ruukki Construction has the right to use CE-marking in their panels. This means that the producer ensures that it will follow all the instructions and regulations set for human health, safety and environmental protection (The European Union 2016b).

The lifetime of the Sandwich panels can reach up to 50 years, provided that the product is receiving regular inspections and maintenance. The surface material is easy to take care of, because it is washable and can be re-coated. The panels can be washed without chemicals, which is a positive feature in terms of environmental impact during its lifetime. It is suggested that the metal surfaces be kept clean. Maintaining and repainting the steel surface will increase its lifetime significantly. Painting can be done with common paint types, thus not being limited by any special characteristic of re-coating substances. (Ruukki Construction 2016a)

4.3 Structure

As stated before, the structure of a Ruukki's Sandwich panel is following: Two steel sheets with mineral wool layer glued in between them. An example of the basic structure can be seen in Figure 11. The steel surfaces of the Sandwich panels are either painted steel plates or processed by another means to be rustproof. The raw material for these plates is hot-dip galvanized steel. Usually the outside surface of the panel is processed with Hiarch-coating and the inside surface is coated with polyester. There are also other possible options for more exotic coatings and special surfaces if the conditions of the operation environment require so. These requirements could be, for example, difficult weather conditions or specific regulations for certain type of facilities. (Ruukki Construction 2016a)

Figure 11: Examples of Ruukki Sandwich panels with mineral wool core and their joints (Ruukki Construction 2016a)

The steel sheets and the mineral wool core are connected with polyurethane glue. This glue is not classified as a hazardous substance. (Pokela 2015) This means that panels do not fall under the REACH regulations as was described in the chapter 3.2.1, giving more flexibility with possible re-use or recycling of material after initial life of the panels.

The insulation used between the surfaces of the panels is mineral wool, often glass wool, which is a composite made from glass and bakelite. In this case, bakelite acts as a binder resin. 80% of the glass used in manufacturing the wool is recycled glass. In this particular case, the used cullet is supplied by companies called Suomen Uusioaines Oy or Envor recycling. Every glass color except for brown, can be used in the process of manufacturing the glass wool. (Kyckling and Vainio 2015)

The optimal kinds of raw material for glass wool are flat glass surfaces like the window glasses. If bottles and other similar containers are being used, there is a possibility that some organic, ceramic or metallic impurities can get into the process, which can clog the machines and hinder the process. Modern windshields of the cars cannot be used at all because they have protective polymer layers embedded within them. The process of manufacturing glass wool does not use any hazardous substances. The mineral wool has below 10% of organic matter which means it is allowed to be taken to a landfill as mixed waste (Kyckling and Vainio 2015). Mineral wool is classified as moderately resistant against mold and other possible growths. Thus, it belongs to the same class as concrete and plastic-based materials. (Nieminen et al. 2013)

4.4 Manufacturing process

Ruukki is manufacturing its Sandwich panel SPA in its plant in Alajärvi. Some other types of panels are produced in other plants of Ruukki. Coils of steel and slabs of mineral wool and components of adhesive are received as raw materials for the panels (Pokela 2015). In this plant, the whole assembly process, including packaging is done. This means that products from this plant are delivered straight to the customer with other ordered materials and accessories. In this chapter the manufacturing process of panels will be described in more detail.

4.4.1 Steel sheets

Steel sheets are being used as outer surfaces of the panels. These sheets are manufactured from the steel produced in SSAB's own steel mill in Raahe. Steel manufactured in Raahe plant is taken to SSAB steelworks in Hämeenlinna where it is cold rolled and coated to be ready to be used in the Sandwich panel. (Ruukki Construction 2016a)

The hot rolled steel produced in the Raahe plant is mainly made from iron ore but one charge of raw materials has also from 20 to 30% of recycled steel. The amount of recycled steel used in the process is limited by the requirements of the blast furnace used. Using recycled steel as part of the raw materials reduces the formation of carbon dioxide emissions significantly. Recycled steel is received, for example, from the residues coming from plant's own processes. In theory steel could be recycled endlessly without cycles reducing its quality and properties. (Ruukki Construction 2016a)

4.4.2 Mineral wool

In this chapter, the process of making mineral wool for Ruukki's Sandwich panels will be described in detail. Ruukki Construction receives its raw materials for Sandwich panels at the Isover plant in Hyvinkää and the findings presented in this chapter are based on information complied during a factory tour done on 2.9.2015 and information received from Isover after the visit. A schematic showing the order of the different manufacturing phases of mineral wool in the Isover plant is seen in Figure 12.

The process of making insulating glass wool begins by smelting the cullet which is used as the main raw material for the wool. Smelting is done continuously in an electric arc furnace. The process doesn’t happen in batches, but rather new solid material is loaded on top of molten one. Because of this type of arrangement, the electrodes of the EAF are located in the bottom of the system smelting the cullet from the bottom to the top. The added solid material acts similarly as slag in smelting metals protecting the molten phase and keeping the heat within it. (Kyckling and Vainio 2015)

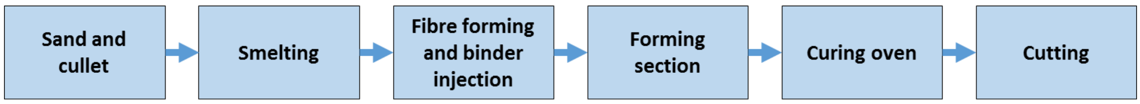

Figure 12: Simplified chart showing the manufacturing process of mineral wool (Kyckling and Vainio 2015)

The next step is the formation of fibers. The molten glass is poured into fiber-producing machines spinning rapidly. The centrifugal force directs the molten glass through small orifices of the container where the molten glass is poured. At the same time it starts to solidify forming long and thin thread-like glass fibers. This new material is collected to a conveyor belt below which it is gathered, forming the so called raw-wool. (Kyckling and Vainio 2015)

At this point, the orientation of the fibers in the wool will be arranged. This is done with using two conveyor belts on each side of the wool block moving at different speed. In this manner, the fibers can be “pulled” upward. The orientation of the fibers has an effect on the insulation capabilities and compressive strength of the mineral wool. (Kyckling and Vainio 2015)

After fiber formation comes the curing phase. In this part of the process, the white raw-wool formed in the previous step is gathered and compressed. Additives such as water and resin acting as binders are injected into the wool. The curing process takes place in the curing oven, where the wool is compressed even tighter and hot air flow is directed through it. In this manner, the wool-binder combination will polymerize forming the desired structure. At this point the color of the mineral wool will turn from white into yellow. (Kyckling and Vainio 2015)

Different types of glass wool could be roughly divided into two different categories. These are so called heavy wool and light wool. In the heavy wool, the fibers are more vertically oriented.

This means that a slab of wool has significantly higher compressive strength and its density is higher. In the lighter wool the fibers are oriented more horizontally, which results in a relatively lower compressive strength, but it has better insulation values as a slab. The optimal diagonal orientation of the fibers in the wool offers properties in between these two extremes. The desired angle is acquired by changing moving speeds of the conveyor belts transporting the wool before the curing oven. After the curing phase, the wool will be cut pieces with desired size. Streams of material coming from the cutting and leveling of edges can be directed back into the process. (Kyckling and Vainio 2015)

4.4.3 Assembly of Sandwich panels

This chapter will describe the assembly process of the Ruukki Sandwich panel in more detail. This is the particular process operating in Ruukki's Alajärvi plant. The following description is based on the data gathered in a factory tour on 7.10.2015 and follow-up discussions. A simplified diagram describing the assembly process can be found in Figure 13.

The production in Alajärvi takes place continuously. The assembly of the Sandwich panel begins with the steel coil handling. Two coated steel coils are unrolled on top of each other and after that the facings of panels are profiled to have a male and a female joint on longitudinal edges of the panel and the order specific surface profiling type on the facings. At the other part of the production line, slabs of mineral wool are taken from the mineral wool stock into a cutting area where they are cut into lamellas. Lamellas are turned 90 degrees after cutting so that the main fiber orientation changes from one panel facing to the next. These lamellas are positioned so that they form a certain type of lamellar structure. The advantage in this arrangement is that end joints of the different lamellas are not all in the same place. Also, this will effect on the strength and stiffness of the panel positively.

This mineral wool core structure is moved in between profiled steel facings and directed to the gluing area to adhere the two facings to mineral wool core. The steel sheets and the lamellar mineral wool core are connected with a thin layer of polyurethane glue sprayed into inner surfaces of the steel sheets. Bonding is done in a continuous double belt press having suitable spacing and compression on the structure of the panel being produced to avoid internal tensions in the panels. The layer of polyurethane is so thin that the steel sheets can be separated from the wool by hand, but thick and strong enough that they do not come apart on their own and to give appropriate mechanical characteristics onto the produced panel. (Pokela 2015)

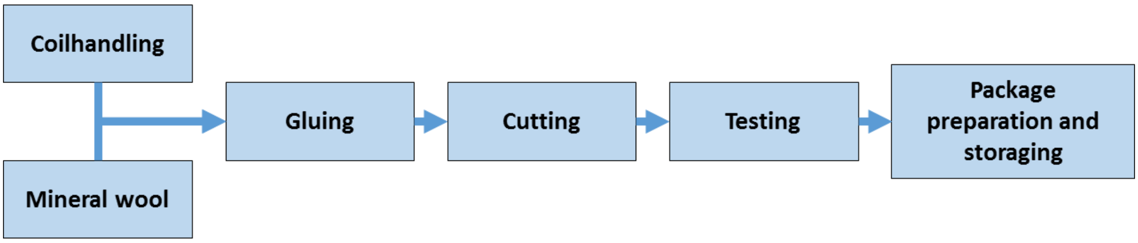

Figure 13: Simplified chart showing the assembly of Sandwich panel (Pokela 2015)

When the structure of the panel is glued together, it is cured with a heated press and afterwards directed into the cutting area where it is sized to fulfill the customer's needs. All of the panels are manufactured for placed orders. The testing phase in Figure 12 is carried out on finished panels. This involved, for example, how well the adhesive had connected the wool and steel sheets. Most of these tests were carried out by hand, with employees testing the joints by ripping the steel sheets off by hand. In addition to manual testing and measurements, mechanical tests are done on panels according to requirements given in the harmonized product standard EN 14509 and other necessary specifications. Completed panels are taken to the packing area where they are finally prepared to be shipped to customers. The packing material has been designed to be easily disposed and recyclable. Ruukki claims that through these preparations, including carefully planned cutting and packaging, their plant will reduce the amount of waste in the construction site significantly. (Pokela 2015)

5. Results

In this chapter, the information gathered during the interviews and plant visits was compiled and put into context. The information was be classified using the same method as that in the previous chapters, based on the five different phases of the life cycle of the product. In addition to this, there is a short overview to the future views in the end.

5.1 Raw materials

The focus in the raw materials was on mineral wool. This was mainly because steel is circulating quite well in Finland. The processes of making steel are generally known and there are many actors in the markets for recycling business. There should not be any problems in getting steel recycled and, for example, SSAB uses a significant amount of steel in their primary steel production (Ruukki Construction 2016a). This creates a demand for steel scrap, which is the major trigger for recycling business.

Mineral wool however is a less known substance. There are different types of mineral wool, but in this thesis the observation is limited to glass wool used in the Sandwich panels, which means that analysis here will be based on the plant visit and interview conducted at Isover manufacturing site. The production of glass wool used in these Sandwich panels was shown more in detail in chapter 4.4.2. The basic requirement to promote ideas of circular economy is that production can be performed with recycled raw materials. At the time of the interview it was stated that 80% of the raw material used by Isover plant in Hyvinkää was recycled glass. The most favorable source of material were ordinary windows. The side streams and excess parts left from cutting can partly be sent back into production to be reprocessed as raw material and partly follow the route of complete products ending up to same place where the Sandwich panels are being recycled. (Kyckling and Vainio 2015)

5.2 Manufacturing

The manufacturing process of the Ruukki Sandwich panels was described in Chapter 4.4. The manufacturing of mineral wool was based on information received form the interview at Isover and the information for the assembly process was received from the interview done at Ruukki Alajärvi. The plant visits provided information on the manufacturing process in general. Raw materials received were the wool from Isover and steel coils from SSAB. These two were connected with adhesive, creating a complete product, which was cut to proper size based on customer’s wishes. The excess pieces were sent to recycling.

At the plant, there was also the testing area where the products were examined to ensure constant quality. These come as a requirement for the CE-marking and they must be done regularly. The requirements for the CE-marking were described in more detail in chapter 2.4.2. Tests on various mechanical properties are carried out. One of these was testing how strongly the adhesive has connected the mineral wool and steel sheets, for example.

5.3 Use

Ruukki Sandwich panels are classified as professionally used construction products, which must have CE-marking included. Getting the marking is a long process, which has many different phases and the mark itself is merely a sign that the procedure has been passed. The procedure was described in more detail in the chapter 3.4.2. The goal of the CE-marking is to bring all the different companies to a same line changing the comparison of brands to comparison of technical properties. The most important document of the CE-marking is the DoP. It has all the information needed while using the product. This will affect also the possibilities of re-using the material after its initial life. The product must still fulfill all the requirements and statements set in its DoP in order to be allowed being sold and used professionally (Viitala and Siponen 2016).

The interview with the Ministry of environment provided some additional information for use-phase of the life cycle of Sandwich panels. The questions about responsibilities are also important. Since the lifetime of a building can usually be measured in decades, the original owner will likely not be the same for the whole time. Problems may rise with revealed mold or other unwanted growths, for example. This may happen either during the use of the building or at the end of its lifetime, which could ruin the possible intents on re-using the construction material. This brings forth again the importance of the information provided in the DoP. If the owner of a building has been able to maintain the building as it was stated in the DoP, the manufacturer of the product is responsible for the condition of the material (Hakaste and Peuranen 2015). Whether a certain product is used in the construction works is ultimately the initiators responsibility (Viitala and Siponen 2016).

5.4 Waste treatment

There is legislation in effect with respect to the treatment of waste, being the reason why an interview was conducted at the Ministry of the Environment. Legislation for waste treatment for the case of Ruukki Sandwich panels comes from three different levels. First, there is the WFD set by the European Parliament and the Council. This sets a framework for member states to operate in. The member states will have to set their own national legislation so that the goals set in WFD are met. They are allowed to set higher goals, but not the other way around. On a local level, the municipalities are the ones who will control that waste treatment is set accordingly through the appointment of environmental authorities. This causes that there may be some changes depending on the area. Possible sanctions from breaking the set rules are stated in the Finnish Environmental Protection Act (527/2014), the Waste Act (646/2011), and the Criminal Code of Finland (39/1889). (Hakaste and Peuranen 2015)

The second level of legislation in the case presented in this thesis is the CPR. It defines how construction products should be treated. An interview with Tukes clarified the scope of this legislation. The interest of CPR is not directly on waste treatment, but rather about the requirements for construction products in professional use. It has however a major impact for re-using and recycling, since it states what kind of products can be sold or used. It sets limits on which parts can be used and what is needed for those that cannot be directly marketed and used as viable construction products. (Viitala and Siponen 2016)

The third level of legislation is the Finnish national Land Use and Building Act (132/1999). It states the responsibilities for different parties acting on the construction site. It states that the initiator of the construction works has to make sure that all the components are suitable for their exact intended use. They must have suitable technical properties and they must not compromise human health or the environment. (Hakaste and Peuranen 2015)

Used Ruukki Sandwich panels are treated as CDW until they possibly get the EoW status. The criteria for EoW were described in the chapter 2.2.1. When this happens, the material ceases being waste and it is no longer under legislation of waste treatment. However, as long as it is considered waste it must be treated as such without exception (Hakaste and Peuranen 2015). Therefore, the recycling of used Sandwich requires the necessary waste treatment and environmental permits, even though it would be only mechanical processing as stated by representatives of Eko-Expert (Hirvensalo 2016).

5.5 Recycling and Re-using

Currently there is only one company in Finland that recycles Ruukki Sandwich panels. Eko-Expert Oy's main business is on the recycling of mineral wool, but they also process Sandwich panels. At the time of the visit, Eko-Expert was processing only unused Sandwich panels and mineral wool. This was because their capacity was filled with the new material, meaning there is currently no interest in expanding to this new field. To use recycled material would require extra bureaucracy and new environmental permits. They stated that even the mechanical processing of "clean" material required certain permits from the local municipality. When asked about the CE-marking it was stated that problems will rise from the fact that recycled material will never match the properties of the original product, meaning that a new acquisition process must be conducted to this new product or material in order to get the label. (Hirvensalo 2016) There was also a misconception that a material or product would lose the marking when it gains the status of waste becoming non-usable. This is not however the case. The real problem is that often, when material is removed from use, its properties are no longer matching those presented in the DoP. The CE-marking itself remains, but the information has changed preventing professional marketing and use (Viitala and Siponen 2016).

On the other hand, re-using the used Sandwich panels has different requirements than recycling. During the interview with Tukes, it surfaced that, if the components of a demolished building are wished to be re-used, they must still fulfill the requirements and properties stated in their DoP included in the CE-marking. It may be unknown if the properties have been preserved in satisfactory level, which means that certain tests must be concluded. This testing may prove to be expensive, which can hinder the re-using business. The requirements for construction products from different stages can be found in the Construction Product regulation (CPR) set by the EU (Viitala and Siponen 2016). The Environmental ministry even claimed that, under current legislation the re-using of construction product in large scale is practically impossible. (Hakaste and Peuranen 2015)

5.6 Future legislation

The world is ever-changing and therefore the legislation must also be refreshed constantly. New and more complicated products are coming to markets, creating completely new cases and exceptions that do not fit the current rules. Every member state of EU can send their own suggestions and questions to the European Commission, who is in charge of processing them and make changes if necessary. As an EU member, Finland should also actively follow and contribute to the discussion and in order to influence on which direction the legislation is developing. (Hakaste and Peuranen 2015)

The EU has set a goal that every member state should reach the minimum rate of 70% by weight of CDW to be re-used, recycled or to receive some other forms of material recovery (2008/98/EC). They are given freedom to choose how to achieve such target, but this has to be reached by the year 2020. This set level may change based on whether the member states can reach it and on the general development of CDW stream. For some countries achieving this target may prove more difficult than for others, because of composition of CDW, an example being the large amount of wooden material used in Finland, as detailed in Section 3.2.2.1.

There has been a discussion of whether a minimum amount of recycled material should be included in new products. Such decision has not been approved, but it is believed that it may surface again in the future (Hakaste and Peuranen 2015). The EU has also set ambitious goals for its plan to implement the idea of circular economy transforming the EU area into a recycling economy. There is already a forecast to increase the EU area resource productivity by 15% between 2014 and 2030. (COM/2014/0398)

6. Discussion

The main challenge for circular economy is to keep the material flow within the system using a closed loop. To succeed, the outgoing stream of waste must be minimized. Because of this, in the case example of Sandwich panels presented in this work, it is fundamental to find a point at the product's lifetime where waste treatment steps in. For waste treatment, the EU has set the WFD which is a set of rules setting the framework for the member states to operate in and provides guidelines towards the best possible solutions (2008/98/EC).

The WFD sets is the "waste hierarchy", which is a multilevel system that suggests in which order different actions of waste treatment should be taken and executed (2008/98/EC). This will act as a guideline for further discussions on which treatment type would be the most sustainable one. The waste hierarchy presented in WFD has five levels. For an ideal circular economy model, only three major methods for treating waste material should be applied: re-using, re-manufacturing and recycling (Singh et al. 2015). However, they are very close to re-using and recycling levels of WFD's waste hierarchy. For this reason, all five levels of the EU's waste hierarchy will be discussed, but the focus will be on these two major levels promoting the goals of circular economy.

The most interesting point in our simplified model of circular economy will be found at the point where waste-treatment steps in after the initial use of a product (Figure 14). There, it will be decided what happens to a material: Will it be disposed or will there be a further use for it. Since prevention of waste is not considered to be a waste treatment method, it is not included as one of the possibilities in Figure 14. Likewise, since energy flows are not shown, energy recovery will be left out.

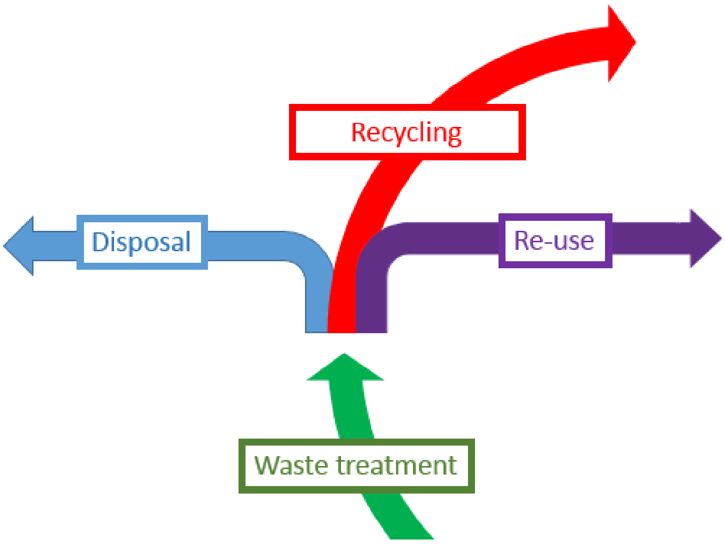

Figure 14: The critical point of circular economy model deciding where used materials will end up.

In the next chapters all the five levels of the waste hierarchy will be considered in detail and its application to the case example of Ruukki Sandwich panel will be discussed along with possible outcomes. Finally, the current situation of CDW will be compared to other specific waste streams and some future recommendations will be presented.

6.1 Reduce

Based on the waste hierarchy set in WFD, the best option would be reducing the amount of waste generated (2008/98/EC). This can be achieved by increasing material efficiency, starting by producing goods using less raw materials and energy (The Ministry of Environment 2013). On the process level reducing is done by optimizing processes to minimize the generation of side streams or excess material. In the product level, the design plays a big role. Products must be designed so they are durable so they don't need to be replaced often, preventing them from quickly turning into waste. Long service life can additionally be obtained by designing products that are being easily maintained (Ellen MacArthur foundation 2016).

To "reduce" in the field of construction products, is mostly about durability. Components have to be weather resistant and by exposure to sunlight must not damage them. Ruukki Sandwich panels are a good example of this kind of product. The steel sheets are highly durable and it is claimed that, with appropriate maintenance, they can last decades (Ruukki Construction 2016a). The core is made of mineral wool, which is also very long-lasting substance. Because the wool is mainly made out of glass or stone it doesn't decompose as time passes, like other polymer-based insulates (Kyckling and Vainio 2015). If the steel sheets remain intact, the wool within is very well protected, making the expected lifetime of the panel to last for decades (Pokela 2015). Compared to some other construction material requiring replacements every ten years this type of durable solution will prevent significant amount of waste being generated.

6.2 Re-use

The second choice according to the waste hierarchy is to re-use the material (2008/98/EC). To achieve this effectively, it would require a careful design of the product so that its technical properties make re-using is possible at all. These products or parts have to be durable enough to remain intact and usable after their initial use with a reasonably low maintenance. The design should also make sure that disassembly of the product is possible without breaking it or damaging other parts associated to it. This feature is particularly important in electrical components. For example if one small component is wanted to be re-used, the circuit board should be designed so that this single component can be removed without breaking other components that could be re-used too. It is generally considered that using glues and other adhesives is a bad choice when assembling a product. Joints sealed by glue generally cannot be opened without breaking them. Many of electrical appliances are put together with glue because they are cheap substances and do not require extra parts like screws or bolts, further bringing manufacturing costs down. Some products are held together with plastic clips that cannot be opened easily and usually break if it is tried to be opened.

Ruukki Sandwich panels have been designed to allow easy disassembling. The panels themselves are connected to each other mainly by gravity and there are no adhesives keeping them together. The panels are connected to a support structure working as an exoskeleton to a building. This structure will carry most of the weight of the building taking the stress off from panels. Ruukki Sandwich panels are easy to maintain and most of the time, they only require washing of their surface (Pokela 2015). If the steel surface remains intact, the panel will stay completely usable for decades. Problems only occur if the steel sheets are broken and water gets into woolen core. Because of the aforementioned properties, Ruukki Sandwich panels would be ideal construction products for re-use. Its properties make it very durable and easily maintained.

Nevertheless, the re-using of construction materials has currently some legislative challenges and difficulties, rather than technical. Although it is not prohibited, the current state of rules and regulations make it virtually impossible to use construction products in professional scale. At the moment there are no economically viable ways to re-use construction material in this scale (Hakaste and Peuranen 2015). The amount of different tests and certificates prevent this from happening, because all regulatory testing must be done on each component separately (Hirvensalo 2016).

The main problem appears to come with the CE-marking, which most construction products are required to have (The European Union 2015). A product without CE-marking cannot be sold as a legitimate construction product (Viitala and Siponen 2016). There has been a misconception that if a product with the CE-marking is removed when a building is being demolished it becomes waste and can no longer bear CE-marking (Hakaste and Peuranen 2015), making it non-marketable. This is only partially true, since waste cannot be used as construction material. However, the end-of-waste criteria apply for construction material: If there is a purpose and demand for it, then it may not be considered as waste anymore (2008/98/EC). In this manner, the CE-marking does not become invalid after the initial use and could remain on the product forever, hypothetically speaking (Viitala and Siponen 2016). What will change are the properties of the material: If a Sandwich panel is in use for 30 years, its properties may be changed. In the case of Ruukki Sandwich panels there can be, for example, some physical damages due lack of maintenance or if water leaks into the woolen core. Such changes may impact the insulation properties of a panel, and may not match the declared values anymore.

Consequently, testing must be done to decide whether the product fulfills the expectations for its intended use in a new location. These tests should be the same as those conducted on the products by the manufacturer to see if they still match the original, declared properties. If they do, then it is allowed to use the material in same kind of use it was before. (Viitala and Siponen 2016)

If the properties fail to match those presented in compulsory DoP coming with CE-marking, the label becomes invalid and the product cannot be sold for same use it was initially intended. If this happens, a new set of tests must be done to determine the new properties for a material along with all other information needed for new DoP. (Viitala and Siponen 2016)

The scale can cause problems. If a large building is being demolished, there will be a lot of potentially reusable material produced. If re-using of parts is desired, there are some requirements to keep in mind. The demolition process must be done so that the materials will remain undamaged, as much as possible. Then, it must be determined which parts are in a condition that they could possibly be re-used. These parts must go to inspection and testing to determine if they actually have their original properties still intact. This means that testing of large volumes of demolition waste would be required (Viitala and Siponen 2016). Evidently, this will demand both time and money up to an extent where this may not be feasible. Along the fact that CDW is very heterogeneous (The European Union 2016c) and volumes are constantly fluctuating, all these most likely mean that organizing re-using of CDW in industrial scale proves to be economically unviable.

One other problem in regulations is that rules are becoming ever more demanding and new standard properties are required as time goes on. If this is added to the fact that lifetime of a building is most likely measured in decades, it will become almost impossible for the material that was designed to fulfill requirements set several years ago to fulfill the current set of rules. This trend applies to both CE-marking and other rules in general. (Hakaste and Peuranen 2015)

6.3 Recycling of material

The third choice from the waste hierarchy is recycling of material (2008/98/EC). This means that after its initial life the product is disassembled, its components sorted and then used again in other products. Recycling is considered to be material recovery.

In the case of Ruukki Sandwich panels, recycling of material appears to be a possible option. These panels have two major parts, the two steel surfaces and the mineral wool core (Ruukki Construction 2016a). The adhesive connecting these two will unlikely cause any problems because it represents a comparatively smaller component of the panel (Pokela 2015). This means that recycling processes can likely neglect the adhesive and focus on these other two major components. Sandwich panels can be disassembled quite easily because the amount of adhesive used is kept at minimum and in practice can even be removed even by hand, leaving most of the woolen core in one piece. This will help the sorting greatly. The amount of wool left onto steel sheets is so low it does not cause problems in the steel recycling process (Hirvensalo 2016).

Recycling of steel should not have any problems, as it is a well-established process and market. In Finland, 94% of steel products are currently received back as material for steel production (Metallinjalostajat ry. 2014). For example SSAB's own steel mill in Raahe uses recycled material in its production. 20 – 30% of the raw material used in their steel production is recycled iron and steel (Ruukki Construction 2016a). Globally, 40% of produced steel is made using recycled material as raw material (Metallinjalostajat ry. 2014).

The main problem of recycling steel is the same as in recycling in general: How to create an effective system to collect the material, sort it, and deliver to the smelter site. To arrange this logistically is especially difficult in Finland where distances are long. The second problem is that volumes of steel scrap vary greatly and are not concentrated in a specific area but rather spread across the country, as a reflection of its low population density. This makes large scale collection particularly challenging.

Ruukki Construction has made a deal with a company called Eko-Expert Oy to process all the flawed and second class panels they produce. They also receive mineral wool straight from other manufacturers. At the moment, Eko-Expert is the only company in Finland that is recycling mineral wool in this scale. In a simplified way, their process consists of separating the steel sheets from the woolen core with a machine that directs steel sheets into a separate area, collects and crushes the mineral wool, and stores it. Eko-Expert is using movable equipment, which can be taken straight into a construction site, reducing the need for transportation and storage. (Hirvensalo 2016)

The separated steel sheets are taken from Eko-Expert by another company called Stena Recycling Oy that delivers them to a smelter as steel scrap where they can be used in steel production. Traces of mineral wool and adhesive are not required to be removed and they can be inserted in a smelter where they will ultimately burn (Hirvensalo 2016). Recycled material is very commonly used also in the primary steel production. It will act as a heat sink and it offers a mean to add different alloys without needing new raw materials (Metallinjalostajat ry. 2014).

At the moment, the mineral wool in general does not have any commonly used large scale recycling options. Mainly it is taken to a landfill or used in a land leveling as a filler material. Landfilling of mineral wool is not a good choice because it mainly consists of either glass or stone that do not decompose easily. Eko-Expert Oy is one of the only few companies in Europe that has is specialized in the recycling of mineral wool. They use crushed wool as air-blown insulate used mainly in renovations of buildings. This recycling business, however, requires special permissions that need to be renewed at regular intervals. (Hirvensalo 2016)

The same problem with CE-marking is also affecting the recycling business of CDW. If a Sandwich panel is recycled, its mechanically separated components cannot be used as construction material. This is because neither steel sheets, nor the mineral wool will be suitable for same kind of use as the complete panel. They also have very different properties that cannot match those presented in DoP of the original panel, which means that they cannot be sold or used legitimately as construction material (Viitala and Siponen 2016). This will limit the possibilities for using the recycled CDW.

6.4 Energy recovery

The fourth option in the waste hierarchy is to use the material in energy production (2008/98/EC). This usually means that waste ending up in this class is sent to incinerator plants where it is burned at high temperature. Waste is thus transformed into ash, flue gas and heat, the latter of which is recovered and used in energy production. Flue dust and ash can be collected and taken into a landfill. Incinerating the waste decreases the volume of burned waste material significantly and produces energy, but results in material losses (El-Fadel et al. 1995). Since after incineration the material is no longer preserved, “energy recovery” does not support the model of circular economy.

Furthermore, in the case of Ruukki Sandwich panels this option is not justified. Neither steel nor mineral wool (Kyckling and Vainio 2015) will burn, which means they cannot be used in energy production. Incinerating is mainly for waste containing large amounts of organic material. These panels contain little to none, meaning they are not suitable material for this kind of treatment. In Finland, the majority of CDW are wood-containing items, which makes energy recovery a popular option in such cases (The Ministry of Environment 2013).

6.5 Landfilling

The last option in the waste hierarchy is to dispose the waste material (2008/98/EC). This means landfilling, which is nowadays seen as the last resort. Material ending up in a landfill is considered lost and is hardly recovered in economically viable ways (2008/98/EC). Lately, the concept of “urban mining” has gained relevance meaning recovery of raw materials from old landfilling areas. This may help cleaning up sites causing environmental hazards, but it would be more sustainable if materials could skip this upcycling phase and end straight into some of upper levels of waste hierarchy.

Landfills are also causing environmental problems. Decomposing organic material will produce methane and other greenhouse gases that end up in the atmosphere. In addition, old landfilling sites that may not be based appropriately and can have leaks containing substances harmful to environment and human health (El-Fadel et al. 1995). Landfilling requires a lot of space, which requires later lots of resources to utilize in some other use after the landfilling site is being closed.

The regulation set for landfilled material states that, from the beginning of year 2016, only 10% of landfilled material can be organic. For CDW, an exception is given, and it has transition time until 2020. Until the end of 2019, CDW can include 15% organic material. This is to prevent most of plastic and wooden materials ending up to a landfill. (Hakaste and Peuranen 2015)

Ruukki Sandwich panels would be among the most harmless objects if they would end up in a landfill. They contain no hazardous materials and they will not dissolve into dangerous chemicals (Pokela 2015). Because of this, they can be considered to be passive waste material. Although landfilling of these panels may be safe and not cause serious environmental impact, the composing materials will still be lost. Because of this, landfilling is not considered to be a sustainable treatment option. In many places around the world however, the only treatment for used mineral wool is to be taken into a landfill or used in land leveling (Hirvensalo 2016).

6.6 Legislative view

Purely from a view of promoting viewpoint of circular economy, the best possible and the most sustainable choice for Sandwich panels would be re-using them, the second best option being recycling. There are however some limitations, which will prevent a choice made solely on sustainable and environmental views. In this chapter the legislation affecting the decision will be presented and summarized. This will be for all the material falling under CDW and therefore apply also for Ruukki Sandwich panels.

If CDW material is to be re-used in a new construction work it has to pass a complicated set of rules coming from three different levels of legislation. The first level of this system is the WFD set by the EU. The second level is the construction product regulation (CPR) set by the

European Parliament and the European Council. The third level stems from the Finnish legislation and it is called The Land Use and Building Act and works on national level. (Viitala and Siponen 2016)

The first step is the most fundamental one. It must be determined if a material or product is classified as CDW. The part 1 of the article 3 in WFD defines waste being "substance or material which the holder discards, intends to discard or is required to discard". The part 5 of Article 3 in WFD defines the producer of the waste as "anyone whose actions produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste" (2008/98/EC). At this point the material is treated as waste and must be treated accordingly. There are two possibilities: either material will be disposed as explained in the article 12 of WFD, or it can be put in use. In order to be utilized again, the material has to pass the end-of-waste criteria presented in the WFD Article 6, meaning it will no longer be considered waste but rather as raw material. In other words, the material or substance must acquire a purpose other than being disposed.

The next issue is to determine if the material or substance will be used and marketed professionally. Basically, there are again two options: either the use will be at a small-scale, private use that happens without commercial transaction, or the material will be sold by a dealer (Viitala and Siponen 2016). A dealer of waste is defined in Part 7 of Article 3 of WFD as following: "Dealer means any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste" (2008/98/EC).

This division between professional "large scale" use and private "small scale" use is important and carries out a long way in the entire system. Either small or large scale, two possibilities according to legislation are: i) the material or products can either be re-used as described in Part 13 of the Article 3 of WFD or ii) recycled as material as described in Part 17 of Article 3 of WFD. The materials without commercial transaction are not falling under the CPR regardless if they are re-used or recycled and thus do not have the CE-marking.

The materials sold by a dealer have different options: The material intended to be re-used can either be used in a way that falls under the CPR, directing it to same direction as materials mentioned the previous paragraph or in a way that it falls under the CPR meaning it can still be treated as a construction product which should have a CE-marking. There are cases when products do not have the appropriate marking, for example because they were produced before CE-marking was mandatory. In this case, the product must enter the procedure for new construction products to earn the marking. If the product or material has the marking, it must be observed whether its essential characteristics still meet those presented in its DoP.

If the essential characteristics still remain, as defined in Article 3 of CPR, the product can be put for sale. This can be done under the old brand or under a new brand as described in Article 15 of CPR. If they have changed and do not remain on the previous level, the material must be put through the procedure to acquire a new DoP and the CE-marking. This is described in Part 2 of Article 14 of CPR. If the brand is to be changed, the product must be taken again through the CPR procedure for new DoP and the CE-marking. Products with active original brand and existing CE-marking do not need this (Regulation (EU) No. 305/2011).

The second type of products sold by a dealer is recycled material. Since the products undergo major changes through the recycling process, it is impossible for them to fulfill their previous essential characteristics presented in their DoP meaning they cannot have an active CE-marking. Because of this, there are two different options: The recycled material will be used outside of construction business meaning it will fall no longer under the category of construction material. In such case, the material will be treated according to the requirements of its new intended purpose requires. The other possibility is to go through the CPR procedure and get the new DoP and the marking.

After the material has all the needed documents, it can enter the acquisition process and be sold to a customer as usable construction product. At this stage the Land Use and Building Act (132/1999) of the Finnish legislation will be enforced. In the construction works there are rules and responsibilities that need to be taken care of. There can be special construction site-specific rules for construction products that do not fall under the category that need the CE-marking. These, along the general quality of construction, are responsibility of the Building Control Department, which acts on a local level (The Building Control of Helsinki 2015). The main responsibility is on the “initiator” of construction works. The initiator is in the end responsible that construction products and materials are used properly and that they are fitting on their intended purposes stated in the documents of CE-marking. (Viitala and Siponen 2016)

The decision-making diagram of the entire process and legislation around it can be seen in the Figure 15. The blue area shows where the WFD is acting, the green area shows where the CPR is acting and the yellow area is where the Land Use and Building Act of the national legislation will rule. There are two major routes presented: One for non-commercialized products and the other for those sold by a dealer. There are abbreviations for Waste directive article (WDA), Construction product regulation article (CPRA), The Land Use and Building Act (Maankäyttö- ja rakennuslaki) (MRL) and Essential characteristics (Ess. Char.). (Viitala and Siponen 2016)

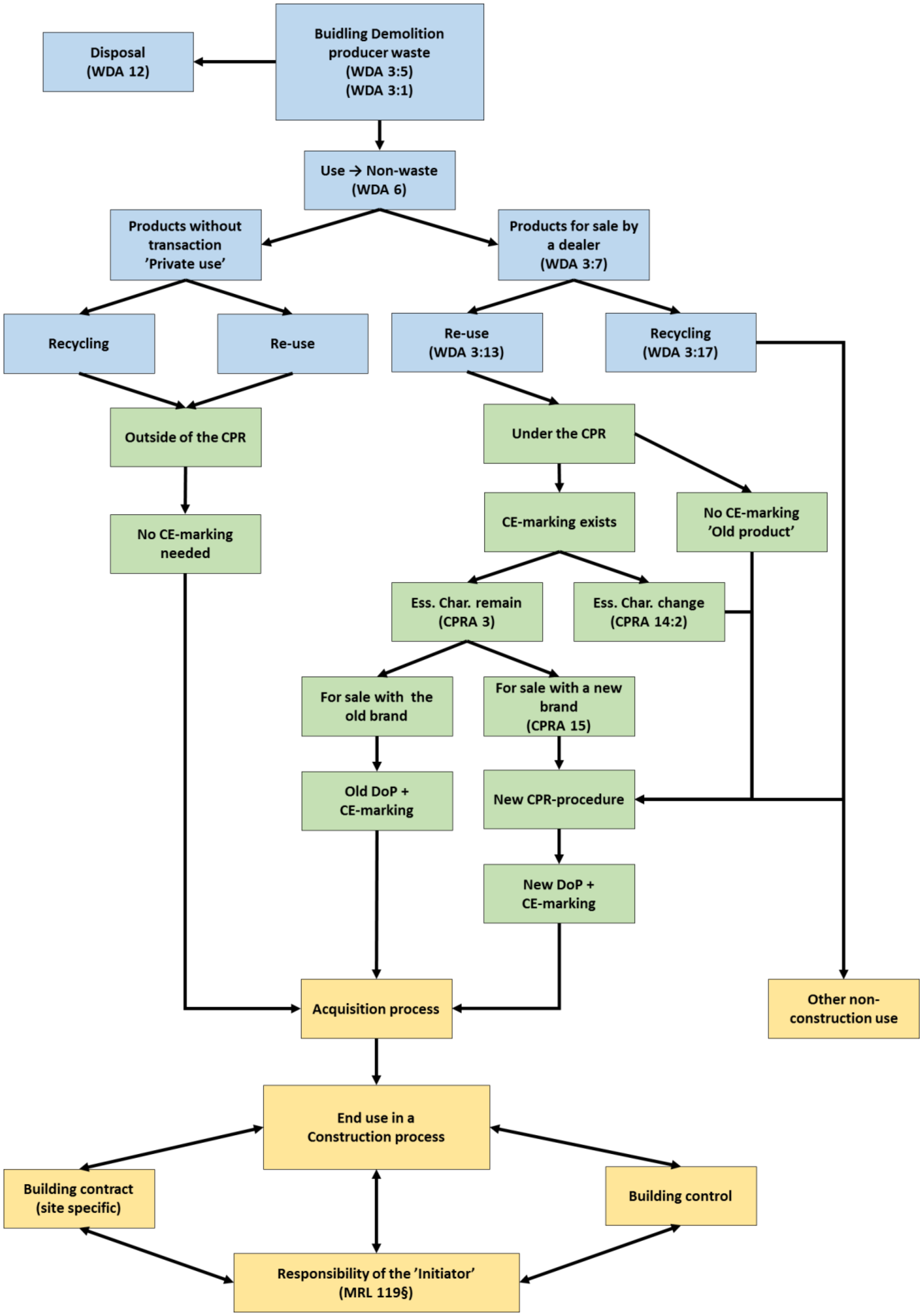

Figure 15: The legislation for different end-of-life uses for a construction product. The blue ones are acting under WFD, green ones under CPR, and yellow ones under the Finnish law (Viitala and Siponen 2016).

6.7 Other views

As mentioned in Chapter 3.1.1, the concept of circular economy involves more than just waste treatment. The design of a product plays a critical part in the future of a material or product. If a product is designed in a way that it cannot be disassembled or recycled economically, even very efficient waste treatment will not help. In this thesis, an already existing product was used as a case example, which means that design-for-recycling -aspects were not considered. The product is considered to be unchangeable and observations are made for this existing item and no changes will be suggested from the perspective of design. It is however acknowledged that design is perhaps the most important factor making products sustainable.

In CRP there is a list of basic requirements for construction works. The list has seven different points or properties that have to be taken into consideration: mechanical resistance and stability, safety in case of fire, health and environment, safety and accessibility in use, protection against noise, energy economy and heat retention, and sustainable use of natural resources. This last one is particularly important for our case and it is stated that:

"The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

(a) Re-use or recyclability of the construction works, their materials and parts after demolition;
(b) Durability of the construction works;
(c) Use of environmentally compatible raw and secondary materials in the construction works." (Regulation (EU) No. 305/2011)

All this comes back to design and planning. To achieve what is being said above not only the product itself has to be designed to be sustainable, but also the process of construction or respectively demolition has to be planned carefully. In order to accomplish this, an effective system for both sorting and collecting should also be set in place.

6.8 Comparison to other waste types

Compared to other waste classes, it would appear that CDW has a narrower set of rules, despite of its massive volumes. These rules seem to be relatively new, since the construction product regulation came into effect in 2011 (Regulation (EU) No. 305/2011).

6.8.1 Waste from electronic equipment

Compared to waste electrical and electronic equipment (WEEE), the set of rules seems to be much shorter. The first WEEE directive came to effect in 2003 and its current version is the directive 2012/19/EU. The rules for WEEE are one of the most detailed set of rules for all of the waste stream categories. The rules regarding treating of WEEE are also based in the WFD and follow the steps of Waste hierarchy. WEEE has been divided into ten different subclasses. Some of these classes are based on physical dimensions of the products and some are based on their original function (2012/19/EU). In the case of CDW the classification system is based mostly on the composition of material itself.

What should be done to make the rules as effective as those for WEEE? WEEE as material differs greatly from CDW. In the case of WEEE, prices of various primary raw materials are very high (The European Union 2016e). This is because most of electrical appliances include valuable metals like gold or copper. In CDW, the situation is different. Most of the materials are bulk substances like wood, steel and concrete, which typically have low prices. The volumes of these two streams of waste are also in very different scale (Statistics of Finland 2013). Possible similarities with CDW are left out mainly because the WEEE directive does not concern large scale fixed industrial installments or large scale stationary tools (2012/19/EU). This leaves WEEE’s focus on smaller equipment.

A second big difference between CDW and WEEE is found regarding the option of re-using components or entire appliances. The technology in electronic equipment grows old quickly and old components cannot be used in modern appliances at all. This fact will eliminate the possibilities for large scale re-using. This means that the main focus for WEEE will be on reducing the waste and recycling. Basic construction material is not affected in the same manner, since as much of it could be re-used.

Collecting and sorting for these two different streams is also quite different. WEEE comes mostly from the smaller size equipment used in common households, which means that people can bring their own old appliances to collecting sites. These collecting sites should be easily accessible, for example, at shopping malls or similar areas near other services or even residential areas. The smaller size and volumes also help sorting procedures. This is evidently different with CDW. Ordinary people cannot transport the amount of waste produced, for example, after demolition of an entire house. Also because of the large volumes facilities for collecting CDW cannot be located in same kind of places like the WEEE collecting points do and require significantly larger storage space.

6.8.2 Waste from mining

The largest waste stream by volume is the waste from the mining industry (The European Union 2016c). Compared to CDW, there are also many differences. The legislation for this stream is focused on initial environmental impact of the mining activities on the area nearby. Mining industry got its first general environmental regulations in the 1950's and the long term planning for the treatment tailings came in the 1970's (Knapp 1989). In the 1980's the environmental problems of the mining industry were disseminated by the media resulting in pressure to implement stringent rules to prevent any worse problems. (Nancarrow and Amirault 1989)

The legislation for the waste of mining industry is a long list. It covers the prospecting, common environmental issues, water bodies, dam safety issues, emissions to air, noise hazardous substances and explosives (Kauppila et al. 2011). There is the waste ordinance for extracted minerals (190/2013) which has detailed rules for treating any waste that mining activities produce. It covers every type of waste that is emitted into the air or water. Mining activities require heavy planning for waste treatment. In short, mining waste legislation focuses on the initial effects of the mine for surrounding area unlike in the CDW, where most of the rules are focused on the waste materials.

7. Conclusions

In this chapter the most suitable solution will be presented. The goal of this work was to promote a circular economy type of thinking and to find the most suitable and sustainable practices for used Ruukki Sandwich panels. Furthermore, it was intended to determine the current state of regulations supporting or preventing the implementation of these potential solutions. As it was stated in the previous chapter, the two most suitable options are re-using the product and recycling the product for material production.

Out of the solutions presented the most sustainable choice which would promote ideas of circular model the most would be re-using of panels as they are. This would skip entirely the processing and manufacturing phases of a new product, which would save resources. As can be seen in Figure 16, bypassing two whole phases will shorten the cycle significantly. This would make it the best solution.

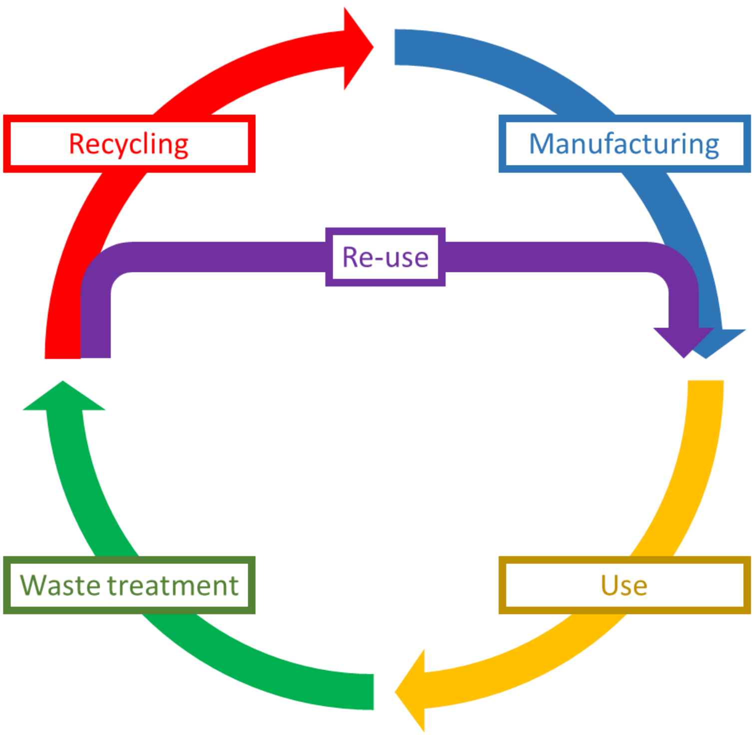

Figure 16: Material flows for recycling and re-using streams for completely closed cycle.

There is also a specific mention about CDW in the EU's plan for circular economy. The markets for recycled CDW already exist and are growing because of the constant need for construction materials. The framework set by the EU commission tells that the environmental factors of the buildings should be assessed more, which will affect also the usage of recycled materials. The goal for the year 2020 is to get 70% of generated CDW to recycling or re-use (COM/2014/0398).

However, there are some challenges. Currently re-using used construction materials as they are after disassembly is not always legally possible. Even if materials would seem to be intact and still possess required technical properties, it is possible that their further use is denied (Hakaste and Peuranen 2015). This may happen, because the material does not have the essential characteristics presented in its DoP that is obligatory with the CE-marking. Without this the material cannot be professionally sold or used as a construction product. (Viitala and Siponen 2016)

To preserve the marking or get a new one for the material, a long list of different requirements must be fulfilled. If the products or materials would go to private small scale use, the legislation is not very complicated, but the main interest is in large scale. If the product is to be re-used and sold professionally by a dealer, it falls under the rules of CPR, which means that a product needs the CE-marking and all the other obligatory documents. This requires extensive testing to determine if essential characteristics of the product remain. If they do remain, the product can be sold and used with its original CE-marking. If the characteristics do not remain the procedure for new CE-marking must be undergone, which means that additional testing and legal work must be done.

If the removed construction product is being recycled through material recovery to be used again as construction material, there is basically only one option. That is to process the material and get a new CE-marking for the product coming out from the recycling process. In this case, it is very unlikely that recycled product has the same essential characteristics as the product it previously was. This leaves the uncertainly out and requires less testing of individual products and makes the process more straight forward.

The recycling business requires also a lot of different permissions. In the case of Ruukki's Sandwich panels, for example, an environmental license is needed to process the mineral wool. This is because the wool is considered to be waste material, thus requiring the licenses to do waste treatment processes even if this involves only mechanical treatment. (Hirvensalo 2016)

Because of the points discussed above, the easiest option for large scale operating would be traditional recycling of the materials contained in Sandwich panels. Sandwich panels have a structure and composition that makes them recyclable with relative ease. Since they consist of only two major components, their disassembly is straight forward. Steel is very commonly recycled material that has many different operators in Finland. The current challenge would be related to mineral wool, since is not very commonly recycled material, as reflected by the fact that there is only one company in Finland currently undertaking its recycling.

8. Recommendations

How could the current production system be improved? In order to adapt to the model of circular economy many things must be changed. Many of them are so large scale changes to the current economic system that may seem unrealistic right now, and implementing them will likely require a long time. The change however, begins from small things and the development should be guided towards the right direction as early as possible. As of today, the change can only be driven by the specific characteristics of each product and the subsequently particular means of reintegration of the market.

Purely from the viewpoint of promoting circular economy the best solution for the case of Ruukki Sandwich panels after initial life time would be re-using them since it is the most sustainable option the EU's waste hierarchy gives us. However, the CE-marking appears to be causing challenges to the re-using business (Hirvensalo 2016). This is mainly because the material used in construction of new buildings is required to have CE-marking and the re-used material lacks the information of its condition after initial use. There is no clarity whether its properties still match those given in the compulsory documents coming with the marking.

It is inefficient to perform all the required tests individually for each component before they can be re-used. There are currently no appointed responsibilities for which party has to do this. In the end, the one executing the actual construction works is responsible that the used material is suitable for this certain use (Viitala and Siponen 2016). Perhaps a standardized system to inspect disassembled parts and evaluating their suitability for re-using could be implemented. In WFD Article 8, there is a mention that EU member states may organize ways to strengthen re-using and recycling through different means (2008/98/EC). Nevertheless, it is important to notice that this is at the moment not mandatory.

The said Article 8 of WFD suggests that the means by which the EU member states "may" guide the waste treatment can be legislative or non-legislative, and can target developers, manufacturers or imported products (2008/98/EC). Perhaps an effective way to promote the re-use or recycling of materials would be to make it compulsory to include additional information into mandatory documents that come with CE-marking. There could be, for example, instructions how to re-use and recycle material and expected lifetime of the product giving some guidance whether the product has preserved its properties and can be re-used.

This would greatly help the re-using business. Instructions like this would give valuable information for consumers on how to re-use their products and reduce the amount of unnecessary testing. There could also be some guidelines that manufacturers would have to provide to determine if the product's properties match those provided in the DoP.

Another view could be required for the definition of waste and how does the title of waste affect the treatment of material in general. Would it bring more new companies and possible investments to the waste treating field if the rules would be somehow more transparent and more easily accessible? Perhaps the EU should publish and official guide for new recycling businesses trying to enter markets. There has been discussion (Hirvensalo 2016) that rules for waste treatment business may be too complicated expelling new recycling companies. This could bring have economical and even political view to this problem.

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10. Appendix

Appendix 1

Interview study, 2.9.2015

Saint-Gobain Isover

Interviewer: Severi Ojanen

Questions about Mineral wool and its manufacturing process. (Interview done in Finnish, questions translated)

- What kind of material is the mineral wool used as the core of Ruukki Sandwich panels; of what does it consist and what is its official name?

- What are the raw materials used in the production; where do they come from and are there any hazardous materials involved?

- How the actual manufacturing process works; are there any side streams and how are they handled?

- Is there different types of wool; how do the manufacturing processes differ?

- How the excess materials from for example cutting are treated; are they recycled or re-used, what kind of information regarding recycling is given to a customer, are there any official recommendations?

- Has there been any testing on how time effects on mineral wool; is there for example estimated lifetime, can unwanted growths or mold occur in time?

- Is there co-operation between Isover and Ruukki for recycling purposes; is there any co-operation in maintenance of buildings, how do responsibilities go between manufacturer and user?

- Can Isovers own plant recycle mineral wool manufactured here?

Appendix 2

Interview study, 23.9.2015

Ministry of the Environment

Interviewer: Severi Ojanen

Questions about Legislation for waste treatment. (Interview done in Finnish, questions translated)

- What kind of legislation there is for treating construction and demolition waste?
- Is there for example a target level for recycling and re-using?
- How do the responsibilities go among the original manufacturer and owners?
- Who is responsible of the quality of possibly re-used material?
- On which level does legislation for waste treatment come from; EU or Finnish legislation and how does it transfer to more local level?
- How are these monitored and controlled?
- Is there any major changes to be expected in the near future and if there is, is there any preparations done in advance?
- Has there been any successful cases of recycling or re-using of construction material like Ruukki Sandwich panels?
- At which point does dismantled material gain the status of waste; how does it effect on further processing?
- How is the idea of large scale re-using of construction materials viewed in general; how does it differ from recycling of material?
- An example: There is an industrial warehouse which is to be demolished and goal is to use the same parts for building same kind of warehouse in another location. Is this possible?

Appendix 3

Interview study, 15.3.2015

The Finnish Safety and Chemicals Agency (Turvallisuus- ja kemikaalivirasto, Tukes)

Interviewer: Severi Ojanen

Questions about CE marking, the meaning and its requirements (Interview done in Finnish, questions translated)

- What does having a CE-marking on a product mean?
- How is using of the CE-marking in construction products being controlled?
- How does the removal of the CE-marking when product gains the status of waste affect its further use?
- How is the use of appropriate products monitored in construction works?
- How could the CE-marking be preserved for dismantled but intact product?
- How could the current system be improved?

Appendix 4

List of disposal operations from the Annex 1 of Directive 2008/98/EC

D 1	Deposit into or on to land (e.g. landfill, etc.)
D 2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
D 3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
D 4	Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
D 5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
D 6	Release into a water body except seas/oceans
D 7	Release to seas/oceans including sea-bed insertion
D 8	Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12
D 9	Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.)
D 10	Incineration on land
D 11	Incineration at sea
D 12	Permanent storage (e.g. emplacement of containers in a mine, etc.)
D 13	Blending or mixing prior to submission to any of the operations numbered D 1 to D 12
D 14	Repackaging prior to submission to any of the operations numbered D 1 to D 13
D 15	Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection on the site where the waste is produced)

Appendix 5

List of recovery operations from the Annex 2 of Directive 2008/98/EC

R 1	Use principally as a fuel or other means to generate energy
R 2	Solvent reclamation/regeneration
R 3	Recycling/reclamation of organic substances which are not used as solvents (including compositing and other biological transformation processes)
R 4	Recycling/reclamation of metals and metal compounds
R 5	Recycling/reclamation of other inorganic materials
R 6	Regeneration of acids or bases
R 7	Recovery of components used for pollution abatement
R 8	Recovery of components from catalysts
R 9	Oil re-refining or other reuses of oil
R 10	Land treatment resulting in benefit to agriculture or ecological improvement
R 11	Use of waste obtained from any of the operations numbered R 1 to R 10
R 12	Exchange of waste for submission to any of the operations numbered R 1 to R 11
R 13	Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced)